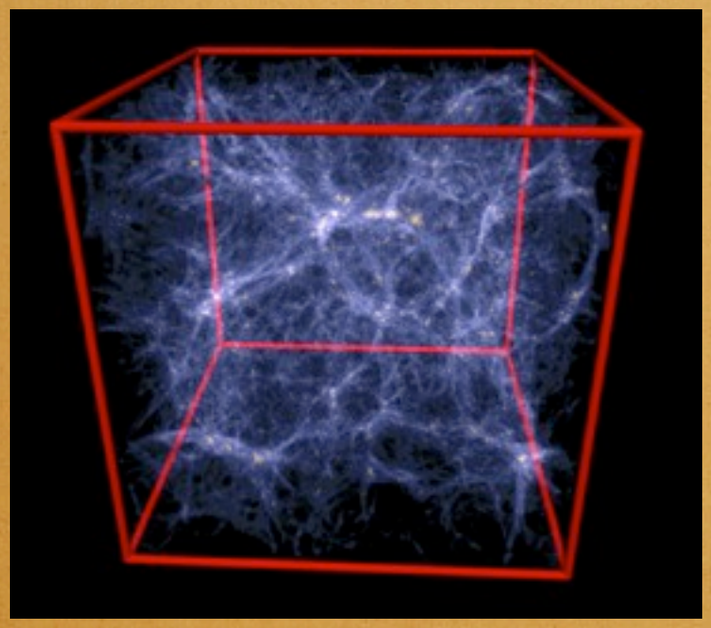
Luminosity Distribution of Gamma-Ray Burst Host Galaxies at redshift = 1 in Cosmological Simulation



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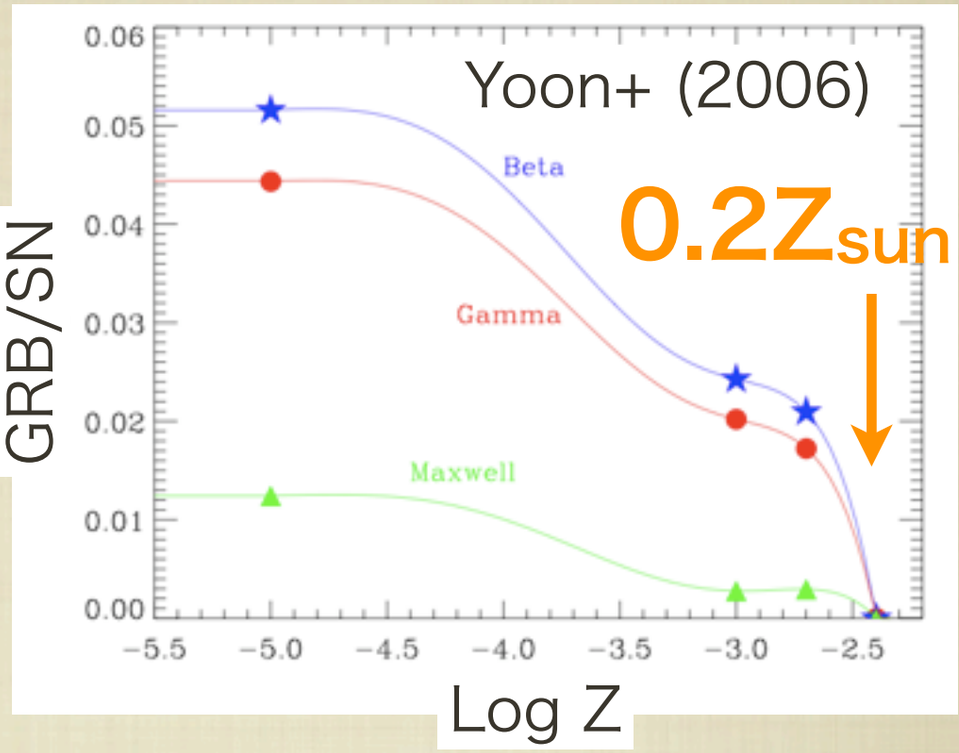
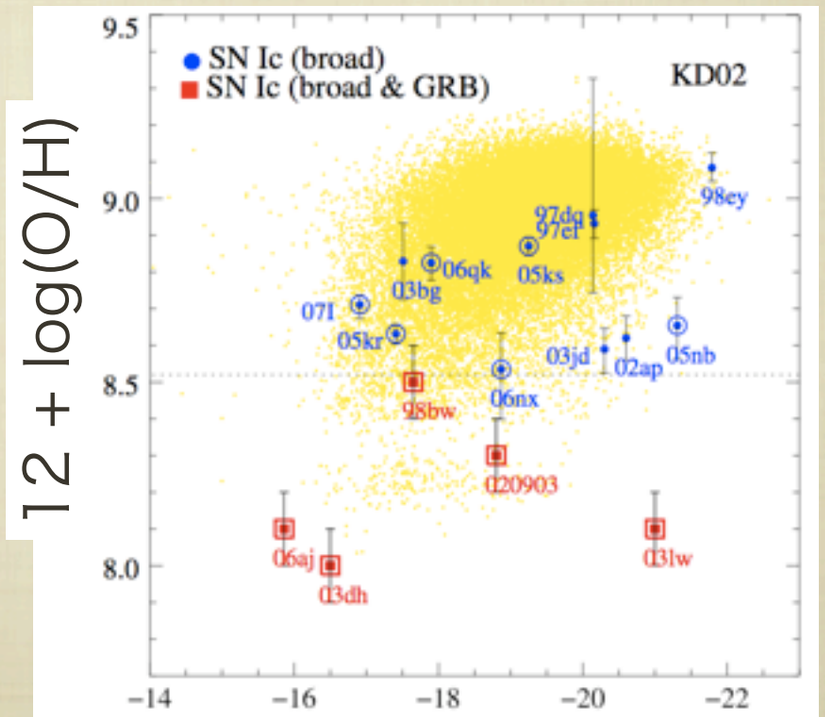
Background

Metallicity of Long GRB Progenitors

- GRBs maybe prefer low-metallicity environment.
  - Studies using stellar evolution model suggest $Z \lesssim 0.1 Z_{\odot}$.
    - Yoon & Langer (2005); Woosley & Heger (2006); Yoon+ (2006)
- Some observations of GRB host galaxies support low-metallicity of long GRB environments
  - e.g. Modjaz+ (2008); Fruchter + (2006); Jakobsson+ (2005)

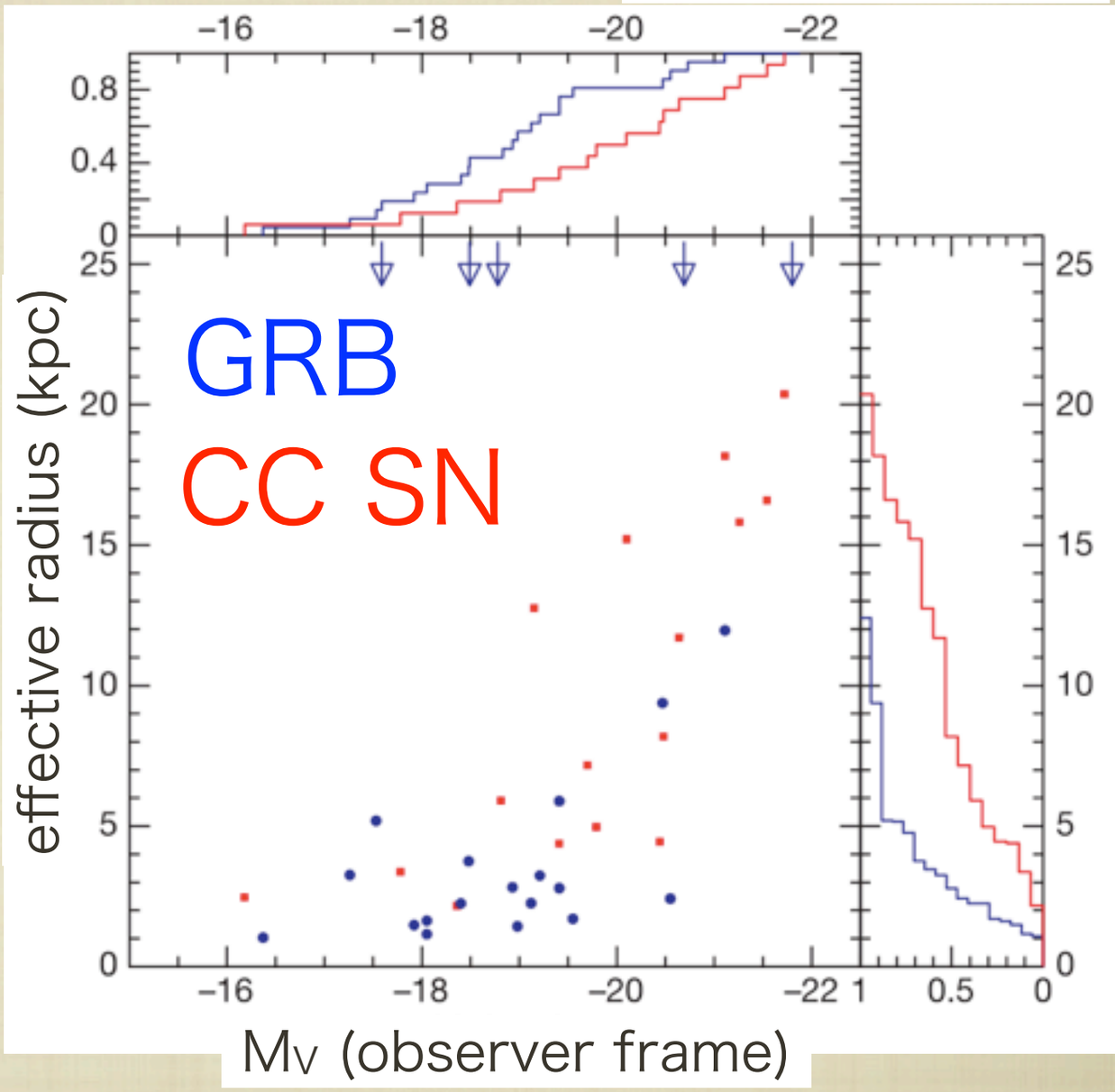




Comparison of GRB/SN Hosts

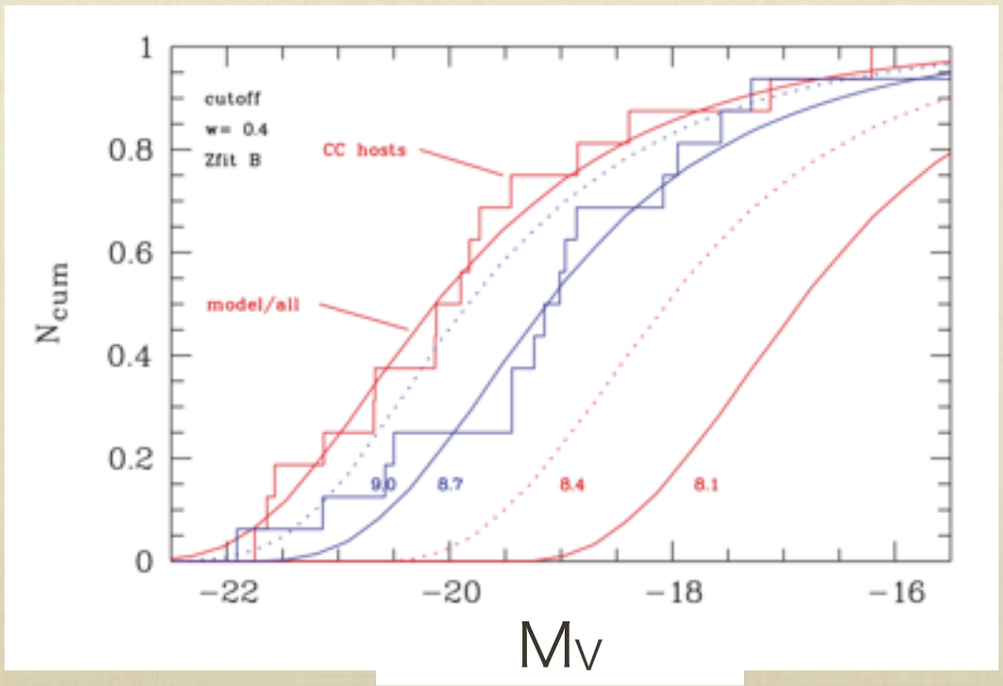
- GRB host galaxies (z ~ 1) are fainter and smaller than core-collapse supernova (SN) host galaxies at similar redshift (Fruchter+ 2006).
- likely low-metallicity environment

Fruchter+ (2006)



qualitatively in agreement, but...

- Wolf & Podsiadlowski 2007
  - Empirical relation of galaxy properties (e.g. L-Z relation) of z~1 galaxies are assumed.
  - GRB can occur ~ $Z_{\odot}$ environment.
    - high-Z than the suggestion of stellar evolution models
- The empirical relations of z~1 galaxies are not well explored.

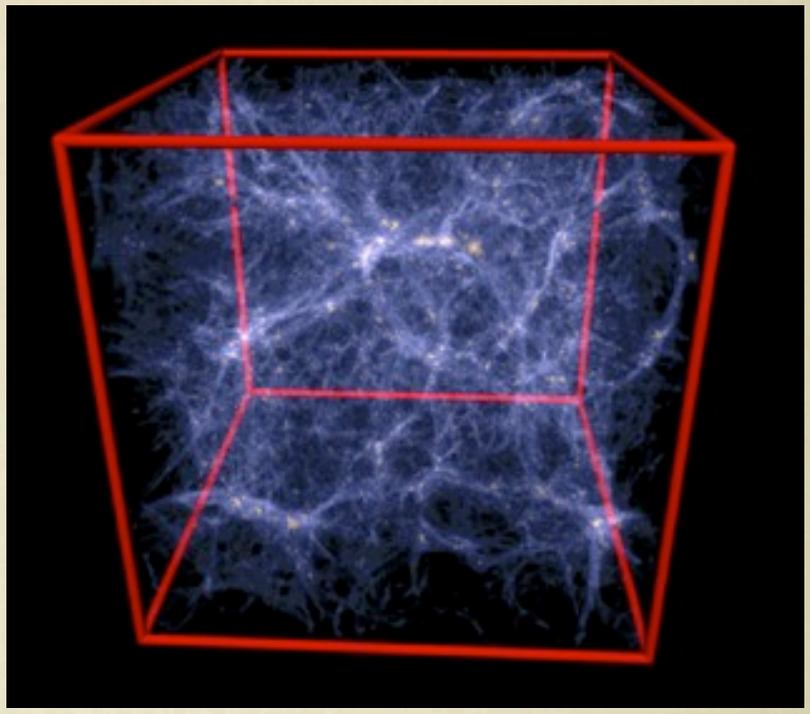


Our Work

Simulating Galaxies at z = 1

Cosmological Simulation

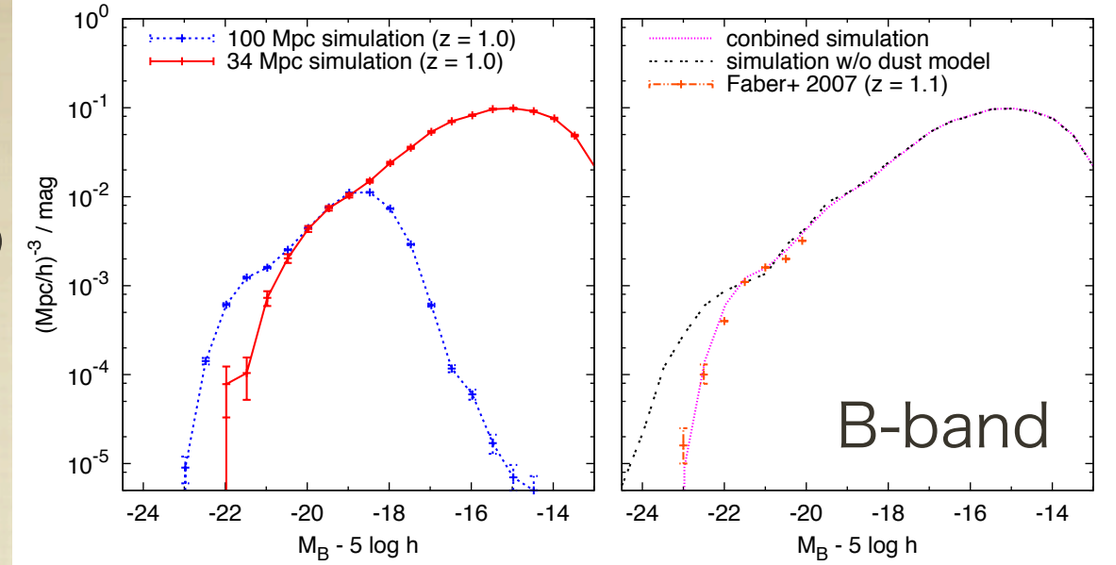
- Smoothed Particle Hydrodynamic (SPH) Code: GADGET-3 (updated version of Springel 2005)
- box size: 34 Mpc, 100 Mpc
  - 400^3 particles for gas & dark matter
    - $10^{7\text{-}9}M\odot$ per a particle
  - Star formation and chemical evolution are computed self consistently during the simulation.
- At z=1.0, each simulation box contains > 10^4 galaxies.

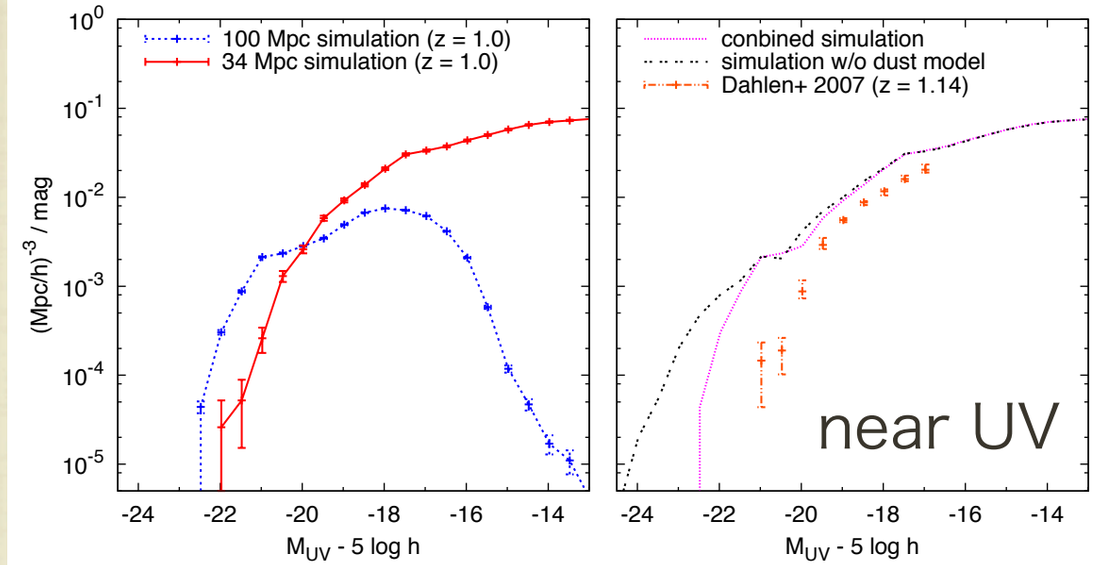


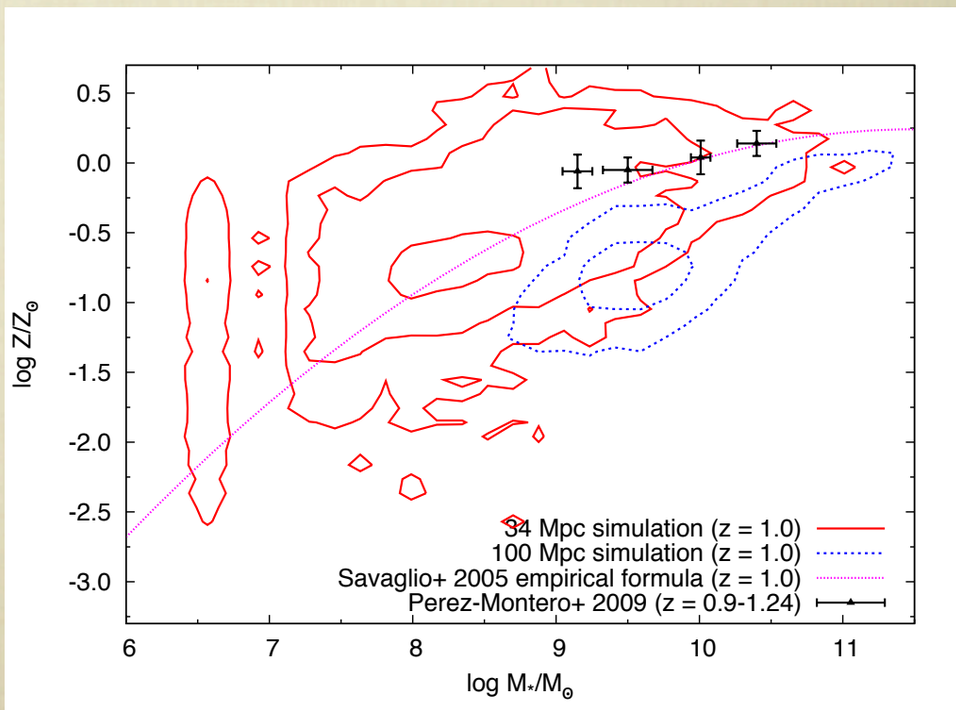
an illustration of cosmological SPH simulation, taken from the website of GADGET-2

Galaxy Properties

- We use GALAXEV (Bruzual & Charlot 2003) to get luminosities of galaxies.
- $A_V \propto$ gas metal column density
  - galaxies treated as one zone
- good in B-band LF and M-Z relation
- overestimation of UV luminosity of brightest galaxies.







GRBs in Simulated Galaxies

GRB rate in simulated galaxies

- Each simulated galaxy contains ~ 30 - 1000 gas particles.
  - $R_{GRB} \propto \Sigma_{Z<Z_{crit}} SFR_{particle}$
- GRB rate to SFR ratio varies in different galaxy.
  - mainly dependent on metallicity

gas particle

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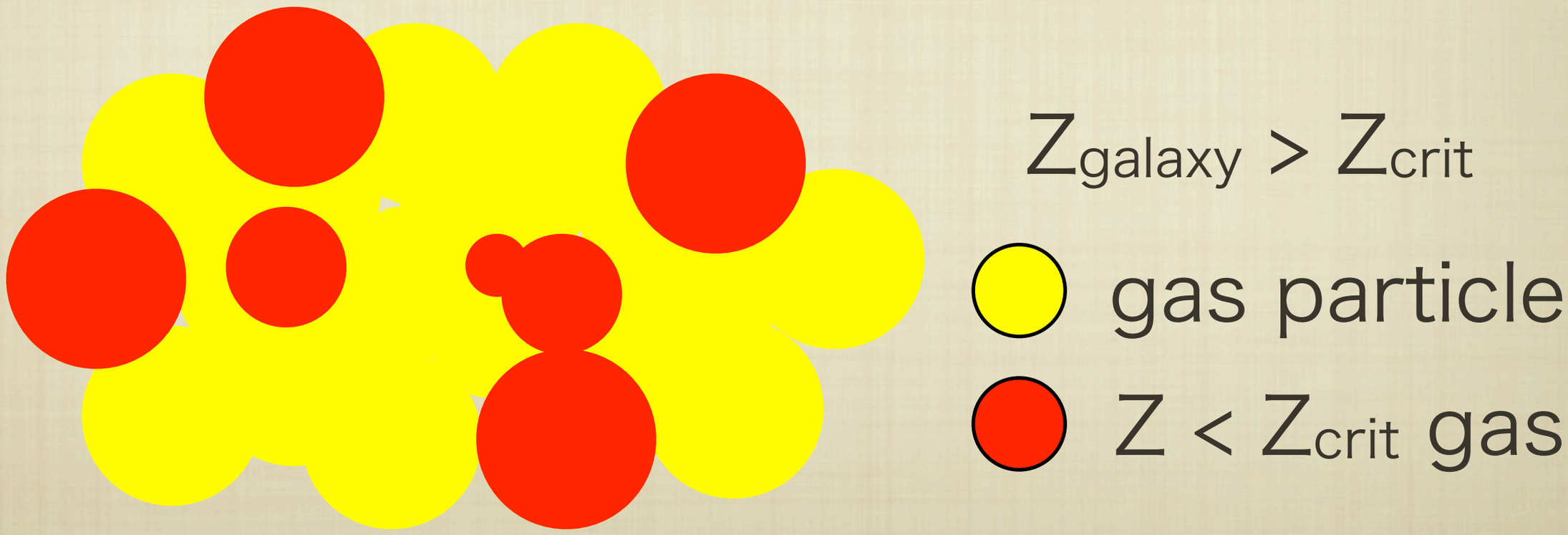

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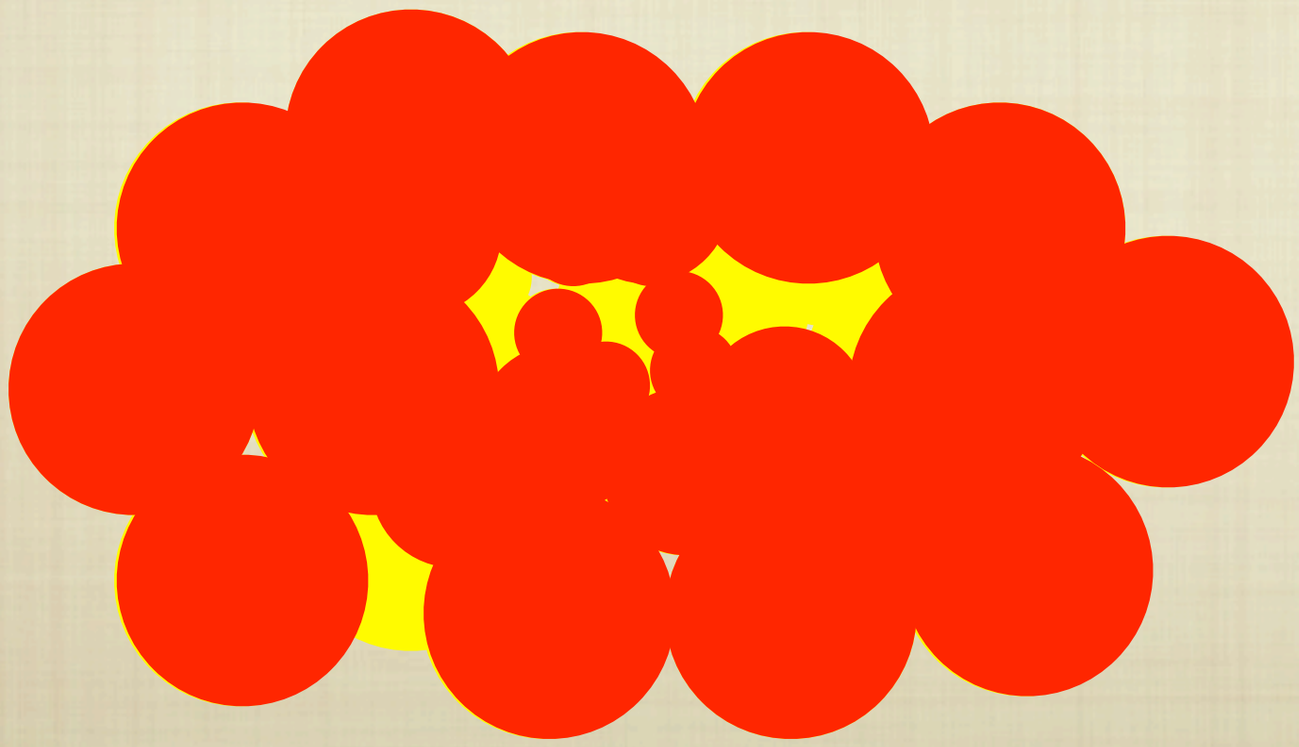
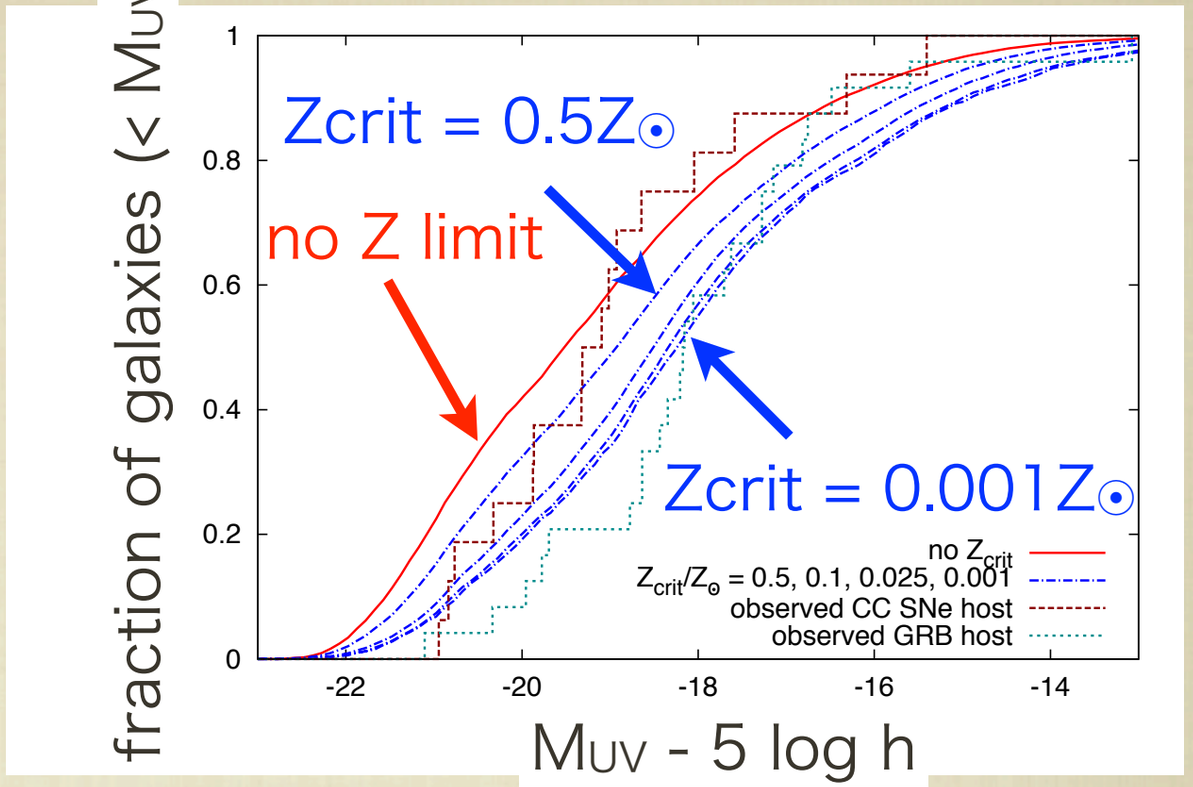


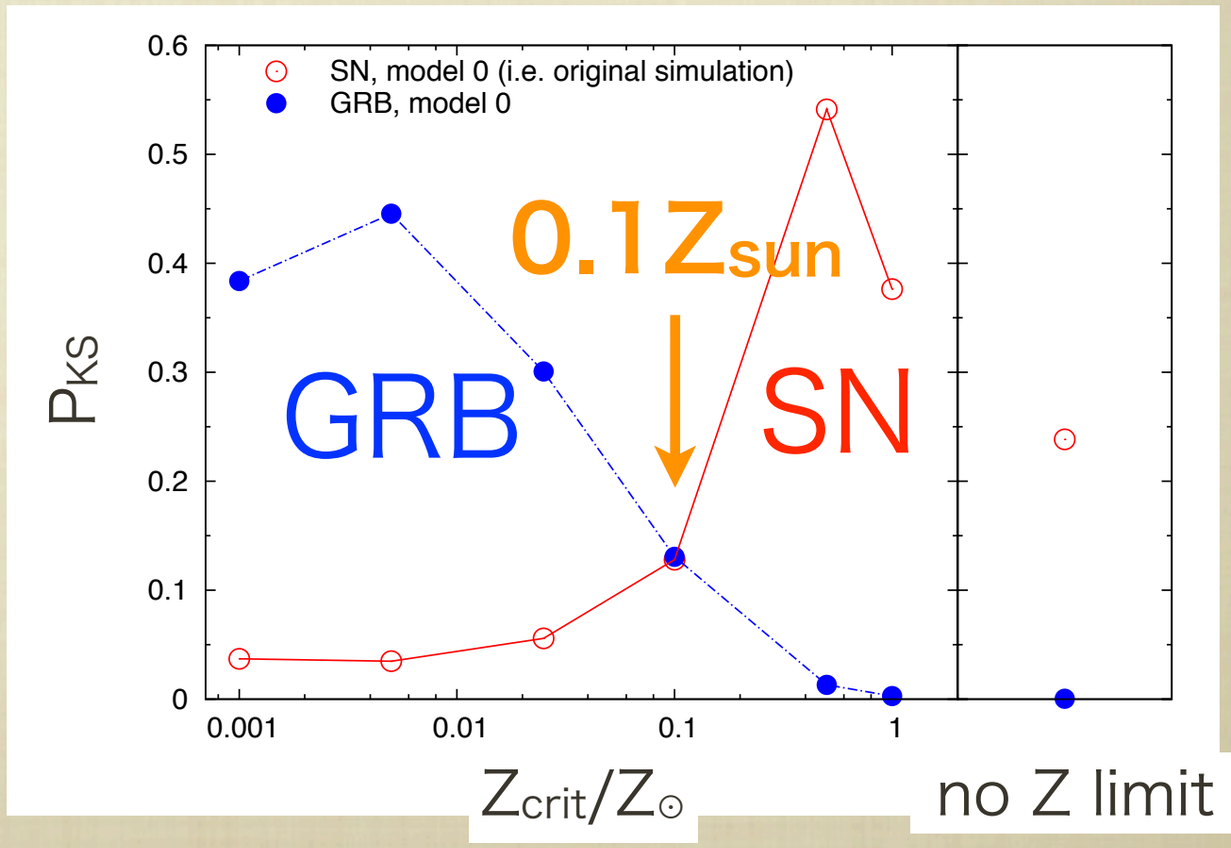
Luminosity of the Host Galaxies

- We weight the sample of simulated galaxies with R_{GRB}.
  - Host galaxies get fainter with smaller Z_{crit}.



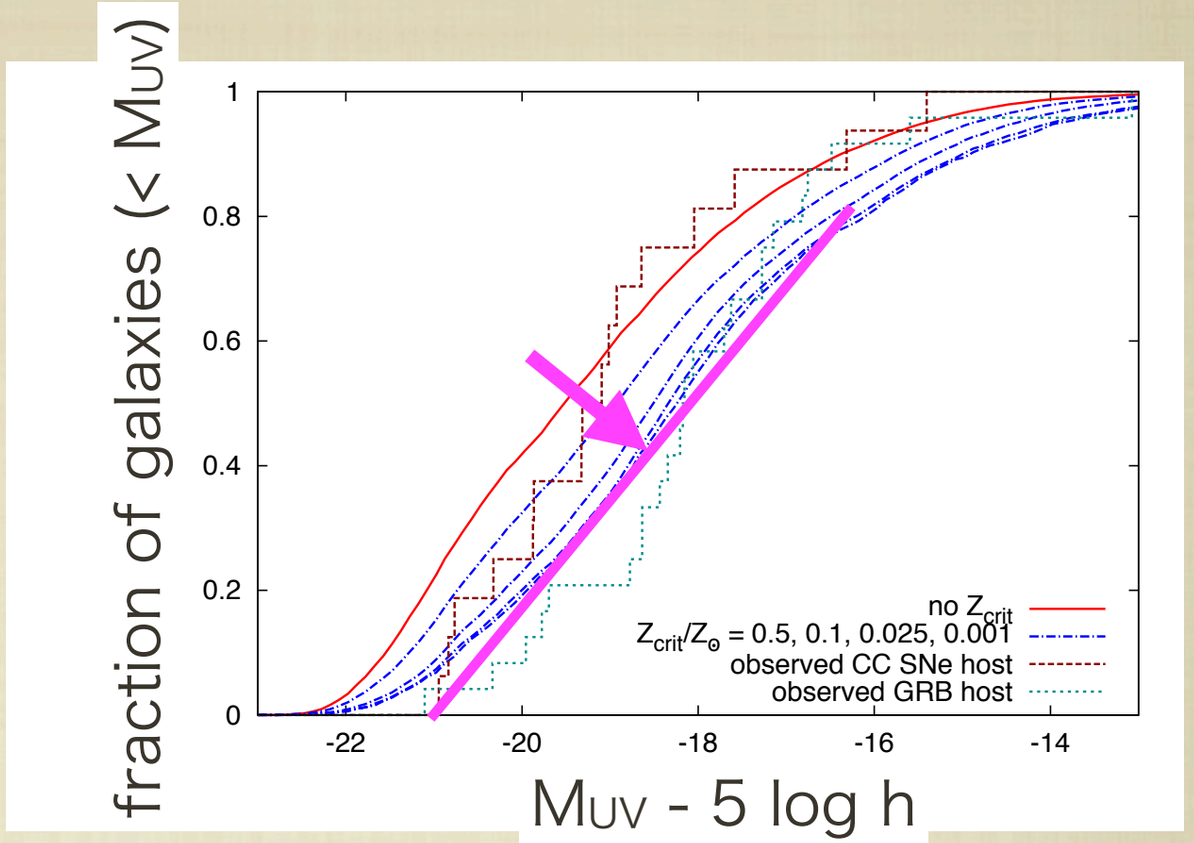
- Kolmogorov-Smirnov test
  - $Z_{crit} > 0.1Z_{\odot}$: SN host
  - $Z_{crit} \leqq 0.1Z_{\odot}$: GRB host

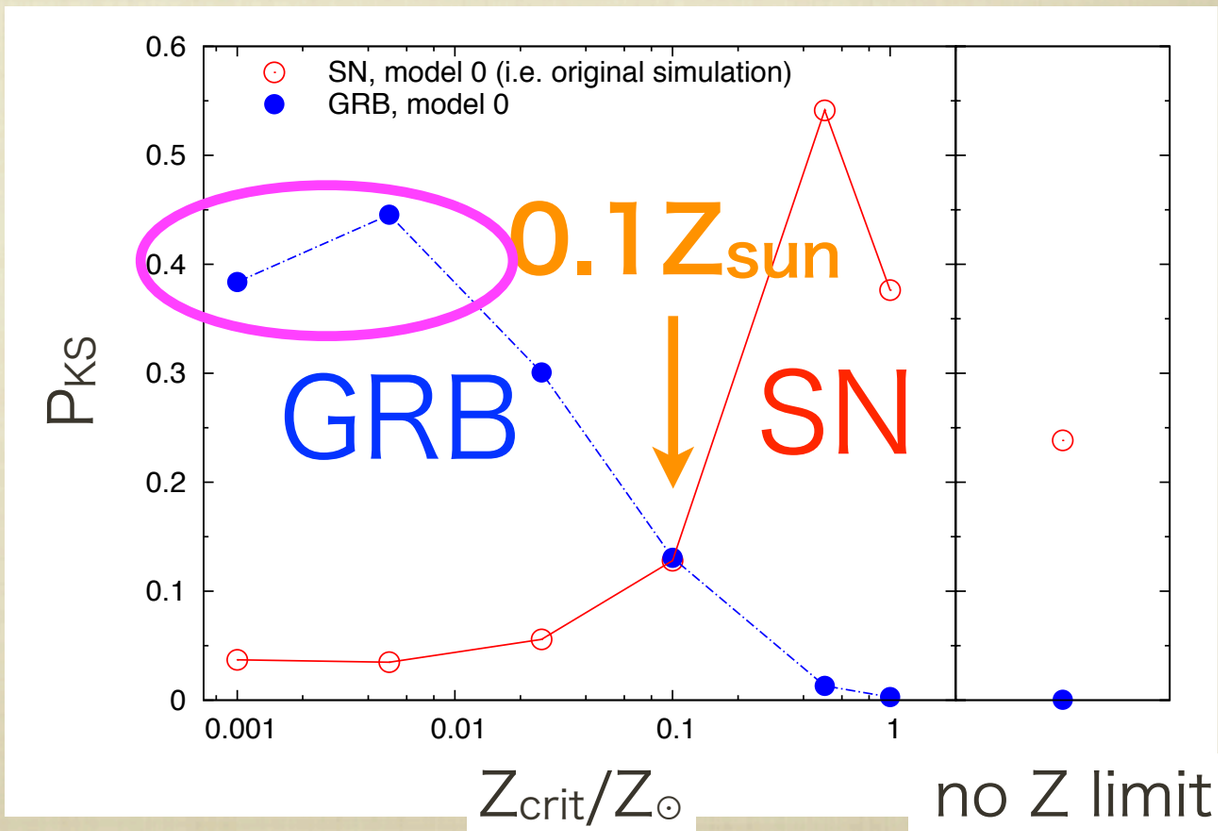
supports studies with stellar evolution models



A Caveat on Resolution Limit

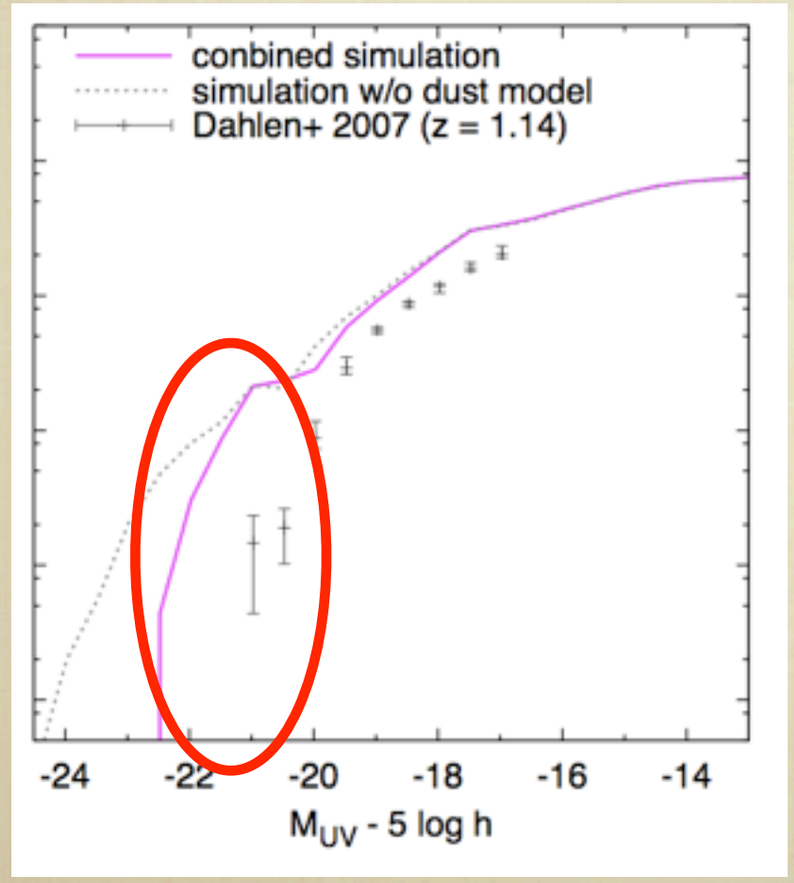
- The host luminosity distribution is insensitive to Z_{crit}, when $Z_{crit} < 0.1Z_{\odot}$.
  - possibly due to resolution limit of our simulation
- Our simulation can not resolve very low-mass galaxies ($< 10^7 M_{\odot}$).
  - Very low-mass galaxies maybe important for very low-metal star formation ($< 0.01Z_{\odot}$).
- We should **NOT** conclude Zcrit ≲ $0.01Z_{\odot}$ is OK.

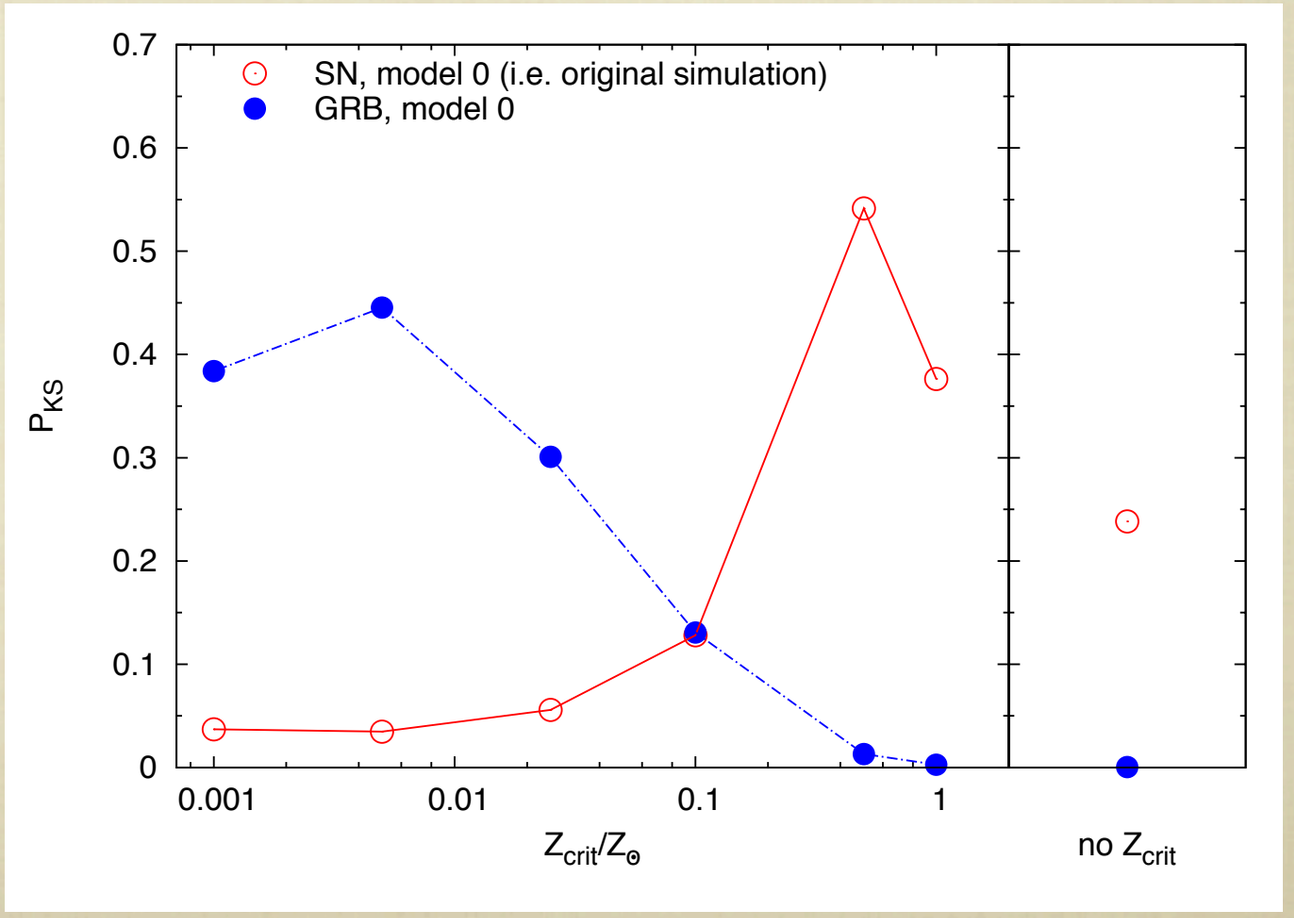




Effect of L_{UV} Overestimation

- ad hoc test to the effect of the overestimation
  - We reduce UV luminosity of brightest galaxies, and see how the results change.
  - The conclusion is not largely affected.
    - $Z_{crit} < 0.5Z_{\odot}$ is favorable.





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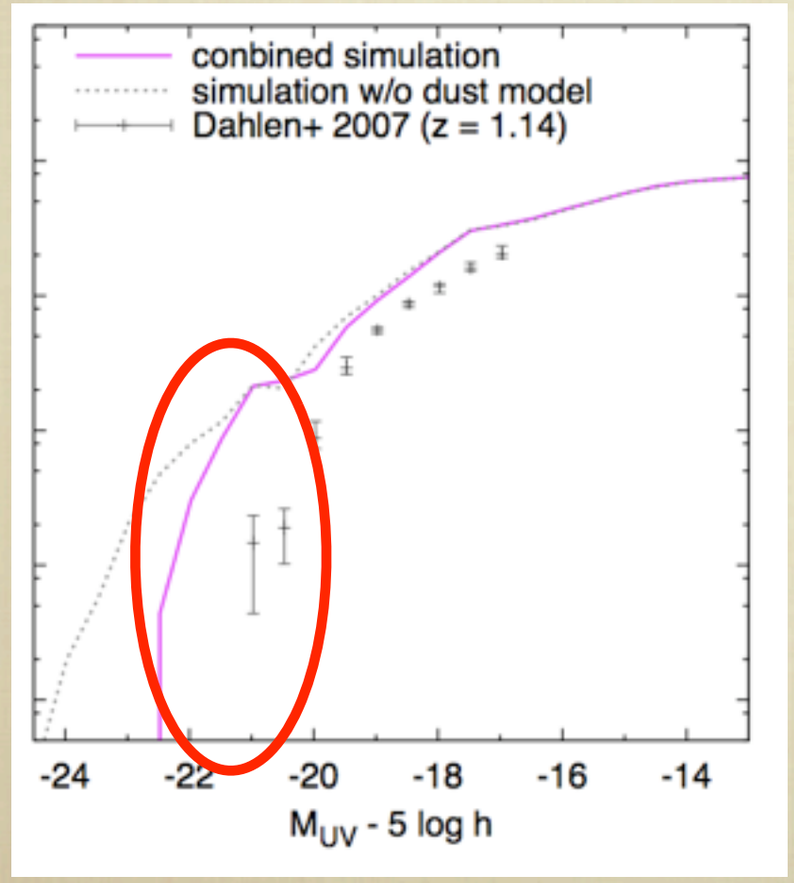
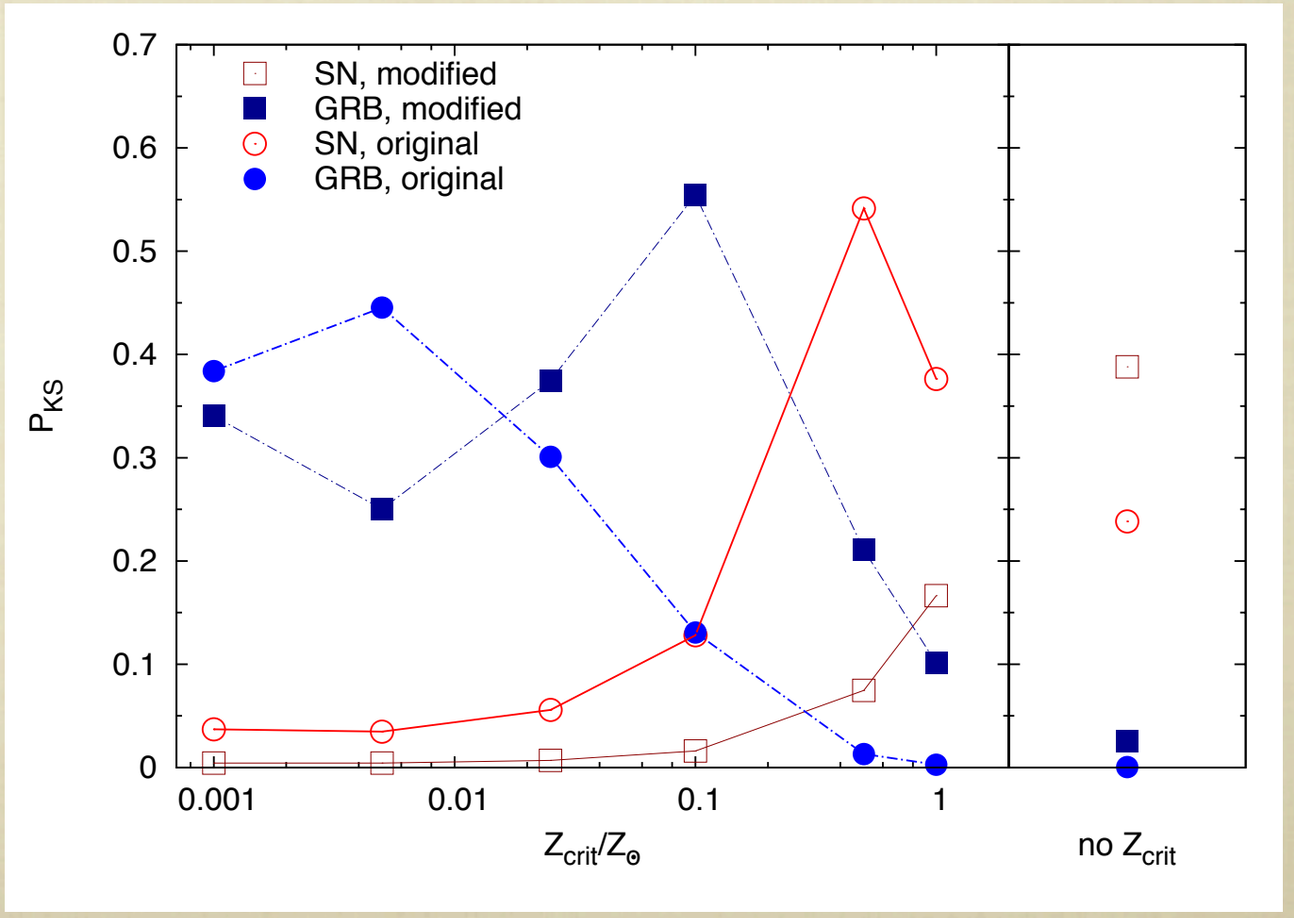
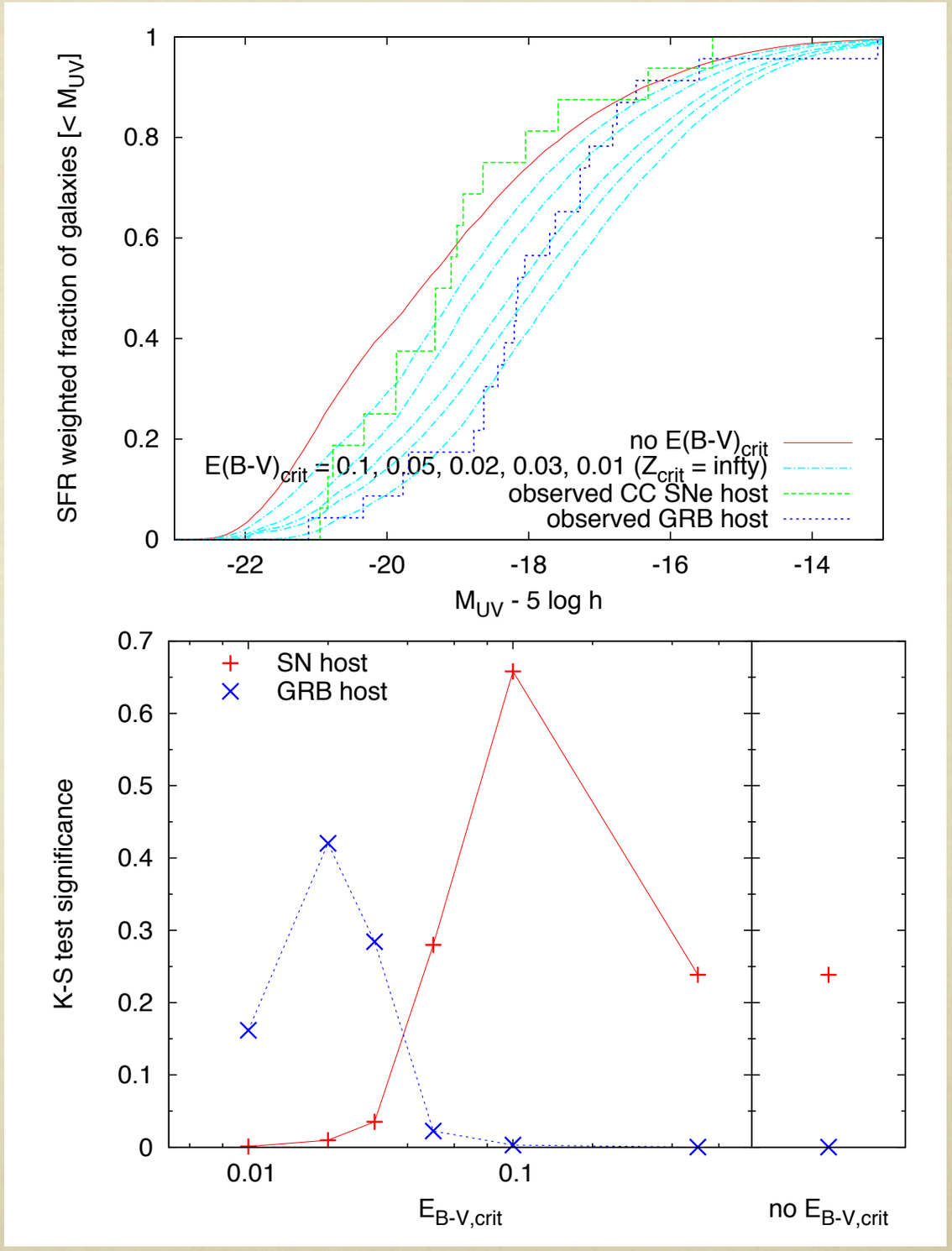




Dust Effect

- We choose $E_{B-V} < E_{B-V,crit}$ as a “identifiable” host galaxies.
  - $R_{GRB} \propto$ SFR in each galaxy.
- $E_{B-V,crit} \sim 0.03$ is preferable to reproduce GRB hosts.

Required $E(B-V)_{crit}$ is not realistic (too small).



Summary

- We have reproduced the luminosity distributions of GRB/SN host galaxies at $z \sim 1$ in cosmological simulation assuming GRBs occur only in $Z < Z_{crit}$ environment.
- **Our results favor $Z_{crit} < 0.5 Z_{\odot}$.**
  - This supports the suggestion of studies using stellar evolution models, rather than previous studies with empirical methods.
- **released on arXiv this Monday (1006:5033)**