Effect of the Cosmological Constant on the number density of Milky-Way-like galaxies

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TABLE 1
SUMMARY OF THE COSMOLOGICAL PARAMETERS OF ΛCDM MODEL[a]

Class	Parameter	*WMAP* 7-year ML[b]	*WMAP*+BAO+H_0 ML	*WMAP* 7-year Mean[c]	*WMAP*+BAO+H_0 Mean
Primary	$100\Omega_b h^2$	2.227	2.253	$2.249^{+0.056}_{-0.057}$	2.255 ± 0.054
	$\Omega_c h^2$	0.1116	0.1122	0.1120 ± 0.0056	0.1126 ± 0.0036
	Ω_Λ	0.729	0.728	$0.727^{+0.030}_{-0.029}$	0.725 ± 0.016
	n_s	0.966	0.967	0.967 ± 0.014	0.968 ± 0.012
	τ	0.085	0.085	0.088 ± 0.015	0.088 ± 0.014
	$\Delta^2_{\mathcal{R}}(k_0)$[d]	2.42×10^{-9}	2.42×10^{-9}	$(2.43 \pm 0.11) \times 10^{-9}$	$(2.430 \pm 0.091) \times 10^{-9}$
Derived	σ_8	0.809	0.810	$0.811^{+0.030}_{-0.031}$	0.816 ± 0.024
	H_0	70.3 km/s/Mpc	70.4 km/s/Mpc	70.4 ± 2.5 km/s/Mpc	70.2 ± 1.4 km/s/Mpc
	Ω_b	0.0451	0.0455	0.0455 ± 0.0028	0.0458 ± 0.0016
	Ω_c	0.226	0.226	0.228 ± 0.027	0.229 ± 0.015
	$\Omega_m h^2$	0.1338	0.1347	$0.1345^{+0.0056}_{-0.0055}$	0.1352 ± 0.0036
	$z_{\rm reion}$[e]	10.4	10.3	10.6 ± 1.2	10.6 ± 1.2
	t_0[f]	13.79 Gyr	13.76 Gyr	13.77 ± 0.13 Gyr	13.76 ± 0.11 Gyr

[a] The parameters listed here are derived using the RECFAST 1.5 and version 4.1 of the *WMAP* likelihood code. All the other parameters in the other tables are derived using the RECFAST 1.4.2 and version 4.0 of the *WMAP* likelihood code, unless stated otherwise. The difference is small. See Appendix A for comparison.
[b] Larson et al. (2010). "ML" refers to the Maximum Likelihood parameters.
[c] Larson et al. (2010). "Mean" refers to the mean of the posterior distribution of each parameter. The quoted errors show the 68% confidence levels (CL).
[d] $\Delta^2_{\mathcal{R}}(k) = k^3 P_{\mathcal{R}}(k)/(2\pi^2)$ and $k_0 = 0.002$ Mpc^{-1}.
[e] "Redshift of reionization," if the universe was reionized instantaneously from the neutral state to the fully ionized state at $z_{\rm reion}$. Note that these values are somewhat different from those in Table 1 of Komatsu et al. (2009a), largely because of the changes in the treatment of reionization history in the Boltzmann code CAMB (Lewis 2008).
[f] The present-day age of the universe.

WMAP collaborators (2010)

TABLE 4

SUMMARY OF THE 68% LIMITS ON DARK ENERGY PROPERTIES FROM *WMAP* COMBINED WITH OTHER DATA SETS

Section	Curvature	Parameter	$+\mathrm{BAO}+H_0$	$+\mathrm{BAO}+H_0+D_{\Delta t}$[a]	$+\mathrm{BAO}+\mathrm{SN}$[b]
Section 5.1	$\Omega_k = 0$	Constant w	-1.10 ± 0.14	-1.08 ± 0.13	-0.980 ± 0.053
Section 5.2	$\Omega_k \neq 0$	Constant w	-1.44 ± 0.27	-1.39 ± 0.25	$-0.999^{+0.057}_{-0.056}$
		Ω_k	$-0.0125^{+0.0064}_{-0.0067}$	$-0.0111^{+0.0060}_{-0.0063}$	$-0.0057^{+0.0067}_{-0.0068}$
			$+H_0+\mathrm{SN}$	$+\mathrm{BAO}+H_0+\mathrm{SN}$	$+\mathrm{BAO}+H_0+D_{\Delta t}+\mathrm{SN}$
Section 5.3	$\Omega_k = 0$	w_0	-0.83 ± 0.16	-0.93 ± 0.13	-0.93 ± 0.12
		w_a	$-0.80^{+0.84}_{-0.83}$	$-0.41^{+0.72}_{-0.71}$	$-0.38^{+0.66}_{-0.65}$

[a] "$D_{\Delta t}$" denotes the time-delay distance to the lens system B1608+656 at $z = 0.63$ measured by Suyu et al. (2010). See Section 3.2.5 for details.

[b] "SN" denotes the "Constitution" sample of Type Ia supernovae compiled by Hicken et al. (2009b), which is an extension of the "Union" sample (Kowalski et al. 2008) that we used for the 5-year "*WMAP*+BAO+SN" parameters presented in Komatsu et al. (2009a). Systematic errors in the supernova data are not included.

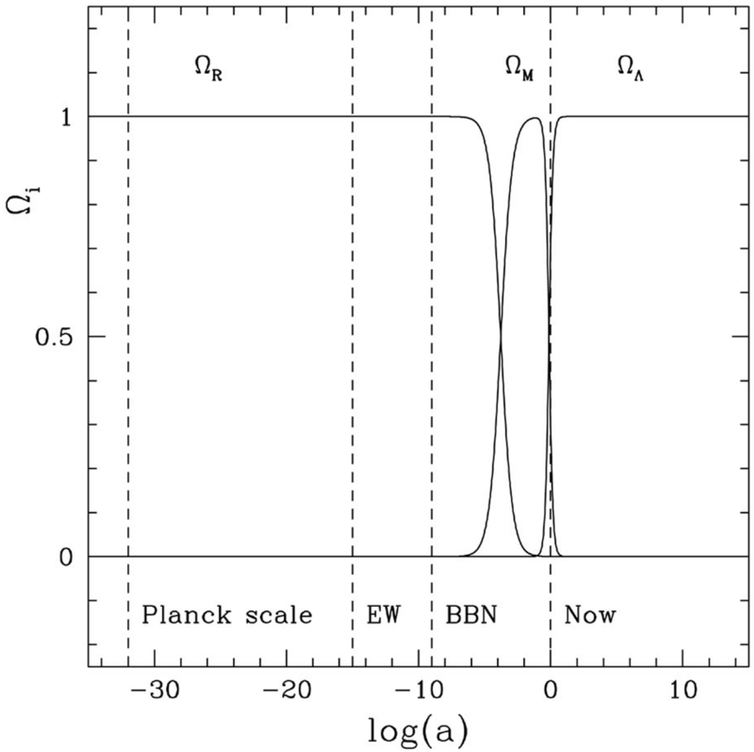
$$w(a) = \frac{p(a)}{\rho(a)} = w_0 + (1-a)w_a$$

$w = -1$ in the case of the cosmological constant

Cosmological constant problem

- (observed value) ~ (theoretical expectation) x 10^{-120}

- $\Lambda \sim \rho_m$ now

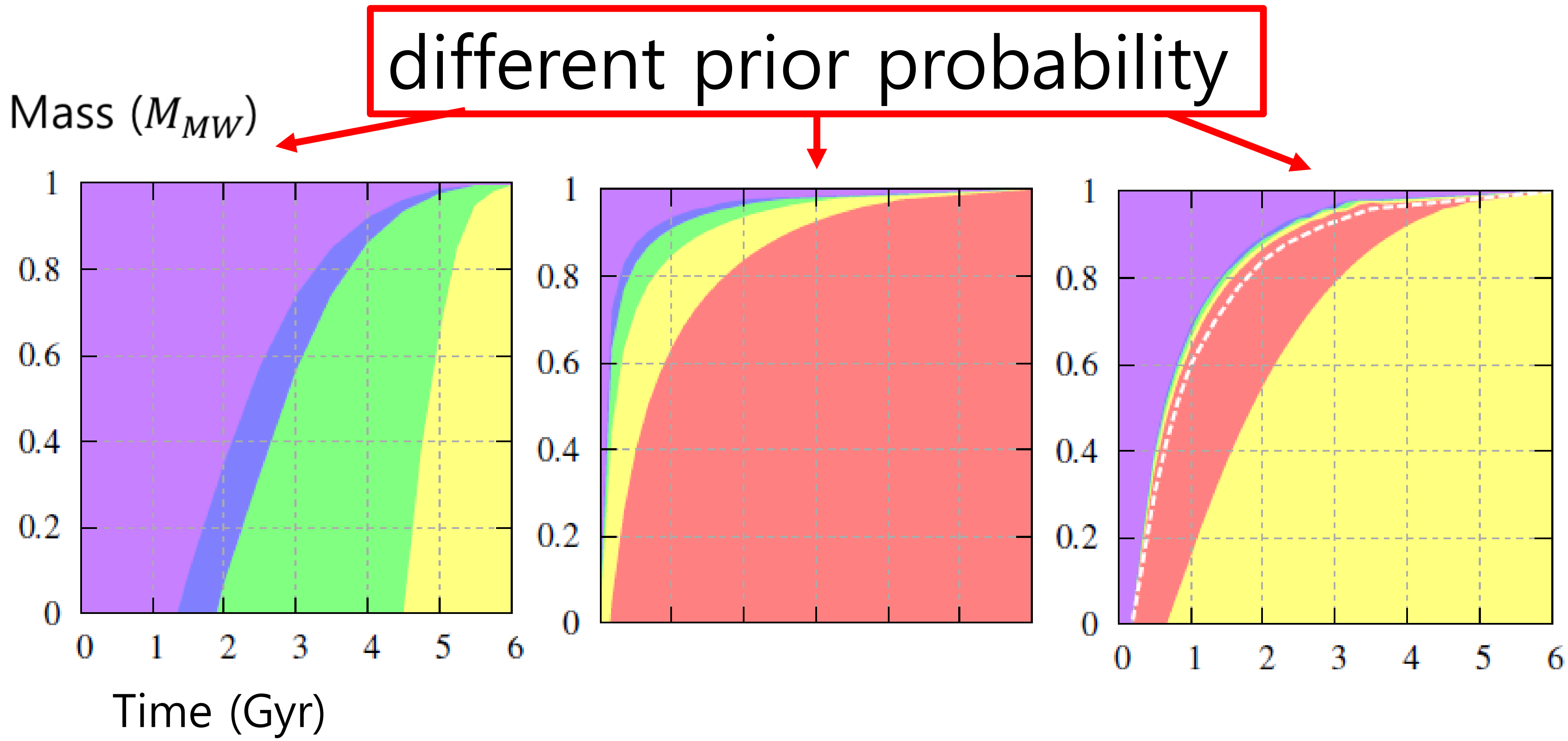


Anthropic selection?

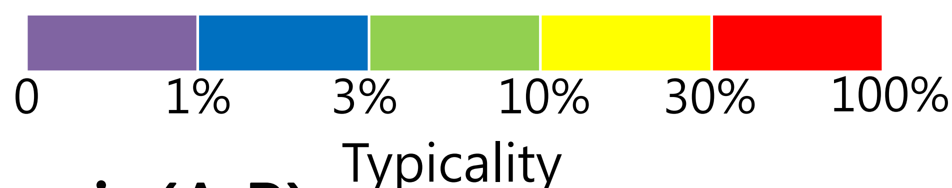
- Understanding cosmological constant problem based on *our* existence… **bold claim!**

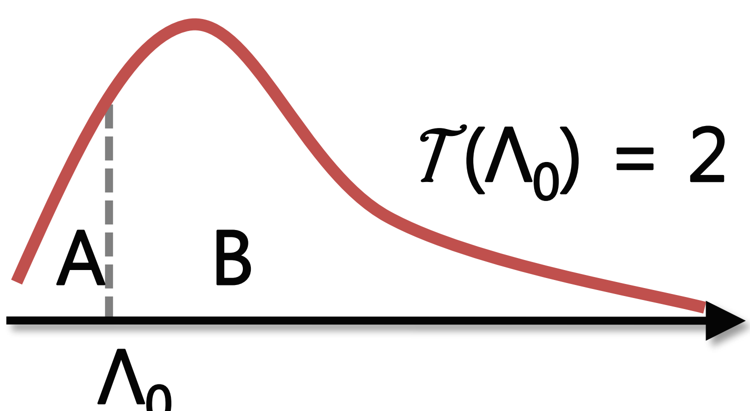
- Even worse, the results are insufficient…
  - whether they use (maybe) irrelevant objects (e.g. massive galaxy clusters)
  - or they rely on purely-theoretical prior probability of universes in the multiverse ensemble

- Let’s focus on where we are… the Milky Way!



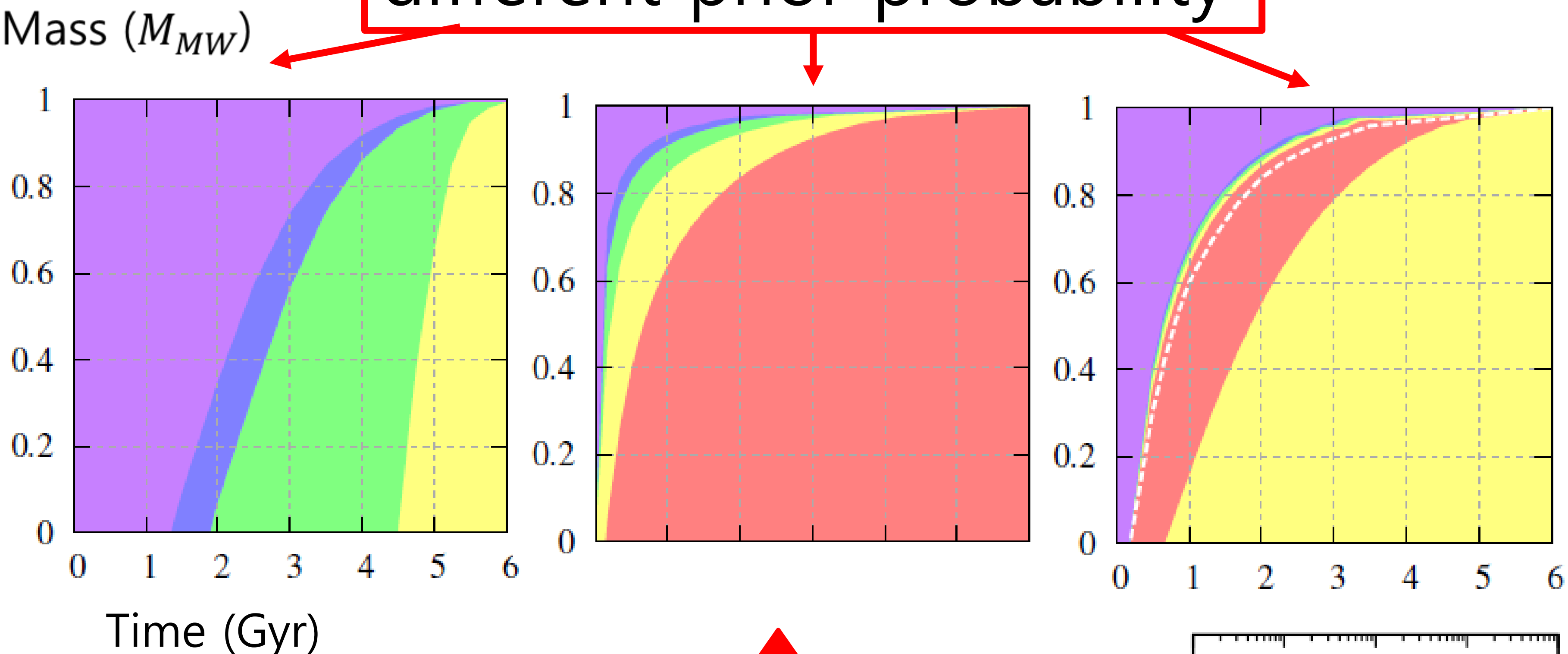
SEH, Stewart & Zoe (2011)





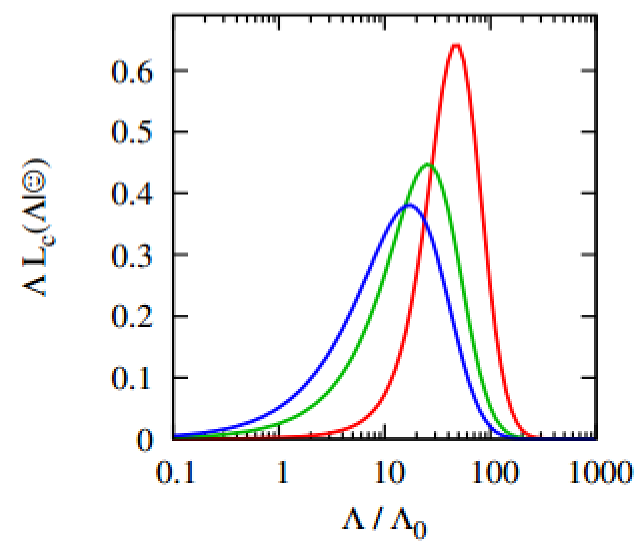
$$\mathcal{T}(\Lambda_0) = 2 \times \min(A,B)$$

different prior probability

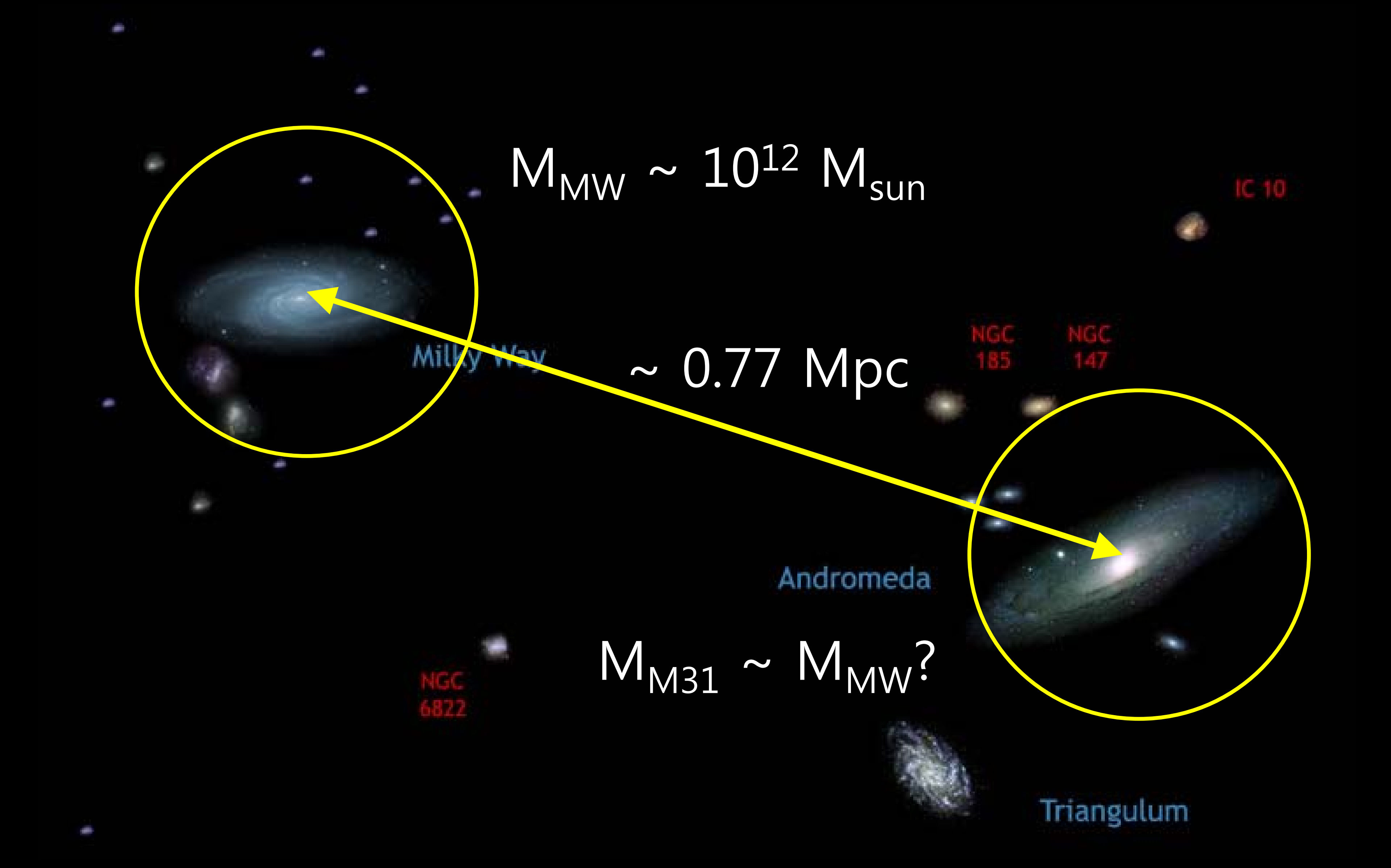


SEH, Stewart & Zoe (2011)

pdf is too broad!



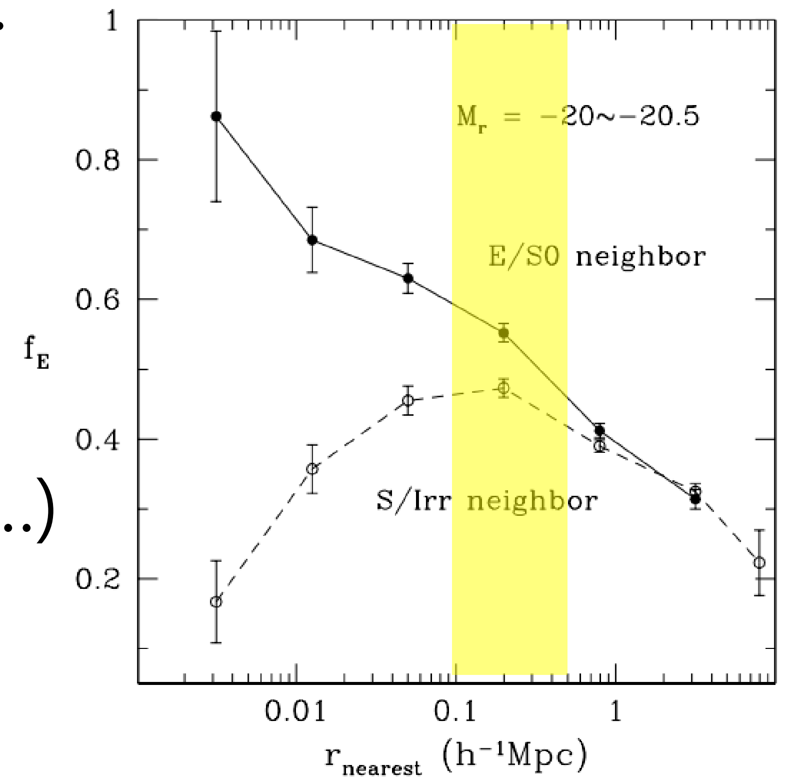
Milky Way & environment?



Andromeda may be important

- Spiral neighbor galaxy with rich metallicity stimulates the star formation of the galaxy when they cross each other.

- Andromeda may enhance the star formation (and the planet formation, …) of the Milky Way



Park, Gott & Choi (2008)

Simulation

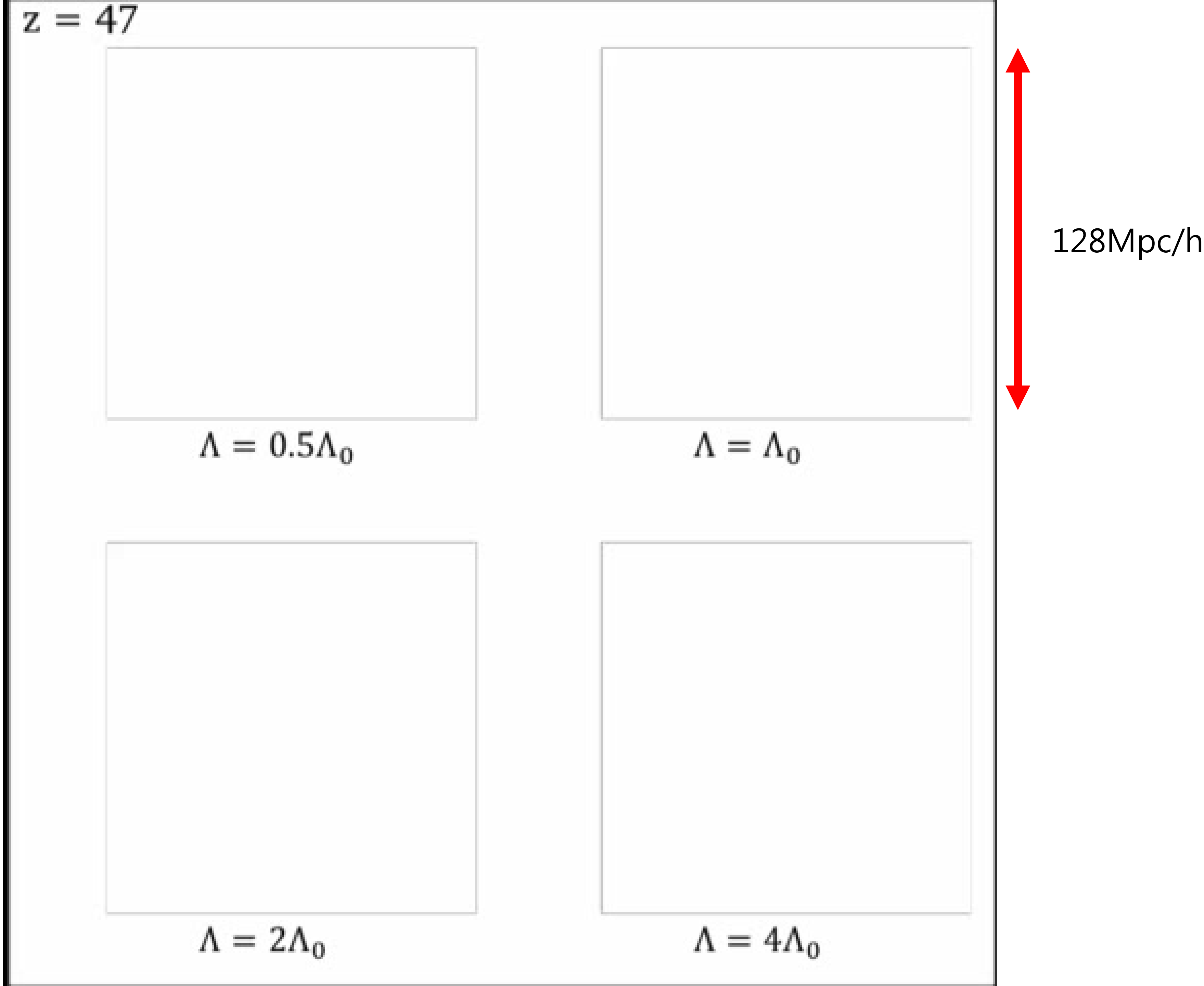
	$0.5\Lambda_0$	$1\Lambda_0$	$2\Lambda_0$	$4\Lambda_0$
Ω_m	0.41	0.26	0.15	0.08
Ω_b	0.069	0.044	0.025	0.013
Ω_Λ	0.59	0.74	0.85	0.95
H_0	0.57	0.72	0.95	1.29
n	0.96	0.96	0.96	0.96
σ_8	0.79	0.79	0.79	0.79
t_0 (Gyr)	15.1	13.7	11.9	10.2

- $\Lambda = \Lambda_0$: WMAP-5yr
- $\Lambda \neq \Lambda_0$: $\rho_{m,b} = \text{const}$
  - $\Omega_{m,b} = \frac{\Omega_{m,b0}}{\Omega_{m0} + (\Lambda/\Lambda_0)\Omega_{\Lambda 0}}$
  - $\Omega_\Lambda = 1 - \Omega_m$
  - $H = H_0 \sqrt{\Omega_{m0} + \left(\frac{\Lambda}{\Lambda_0}\right)\Omega_{\Lambda 0}}$

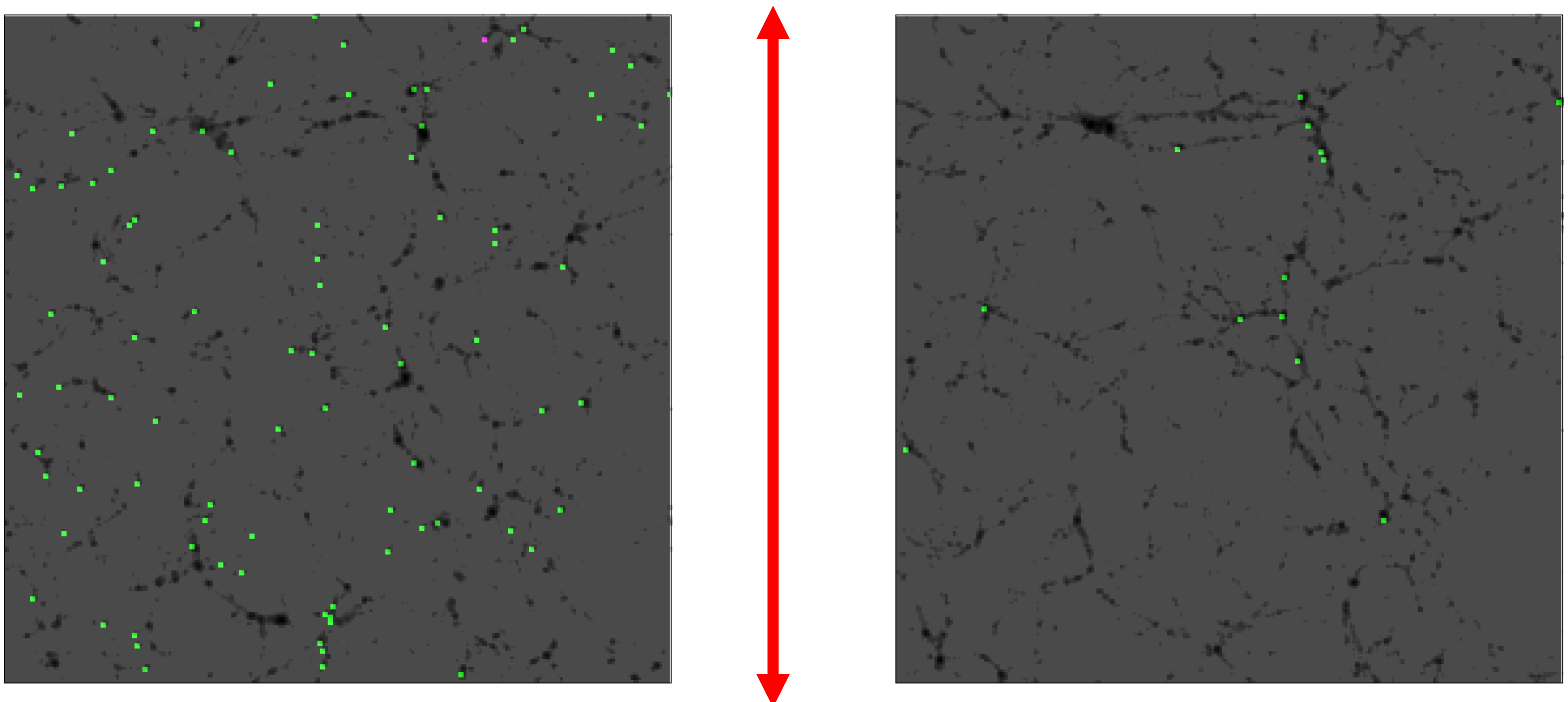
Simulation

- N-body: GOTPM (Dubinski et al. 2004; Kim et al. 2009)
  - 256^3 particles
  - 128 Mpc/h comoving boxsize
  - Halo mass resolution: $9 \times 10^{10} M_{sun}/h$
    - 1.6×10^{11} M_{sun} for $0.5\Lambda_0$
    - 7.1×10^{10} M_{sun} for $4\Lambda_0$

- Milky-Way-like target selection
  - Mass: $\sim 10^{12}$ M_{sun}
  - Mass ratio to the nearest halo: 1~2
  - Distance to the nearest halo: ~770 kpc


z = 47
Λ = 0.5Λ0
Λ = Λ0
Λ = 2Λ0
Λ = 4Λ0
128Mpc/h

Mass



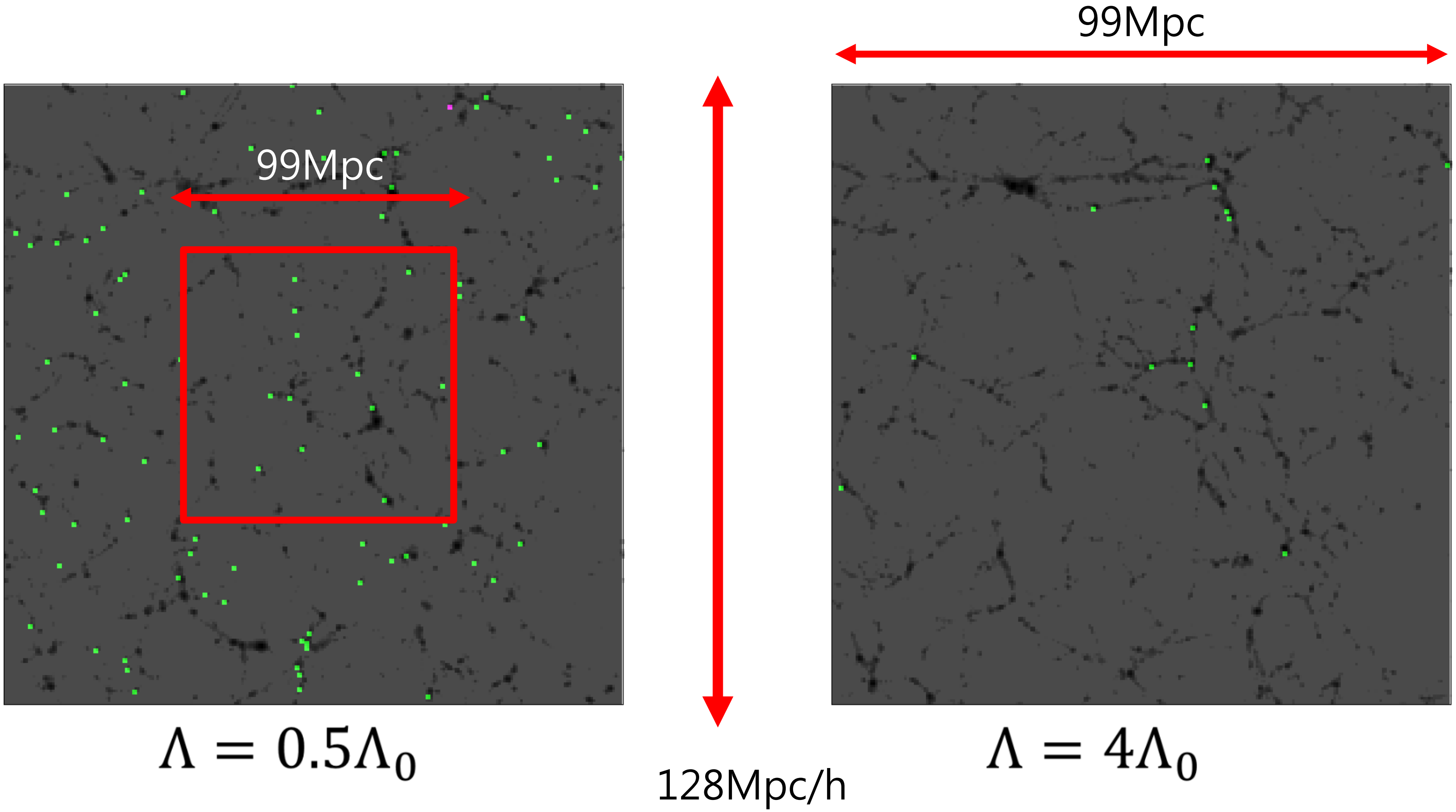
$\Lambda = 0.5\Lambda_0$

128Mpc/h

$\Lambda = 4\Lambda_0$

$$0.8 \times 10^{12} \leq M/M_{\text{sun}} \leq 1.2 \times 10^{12}$$

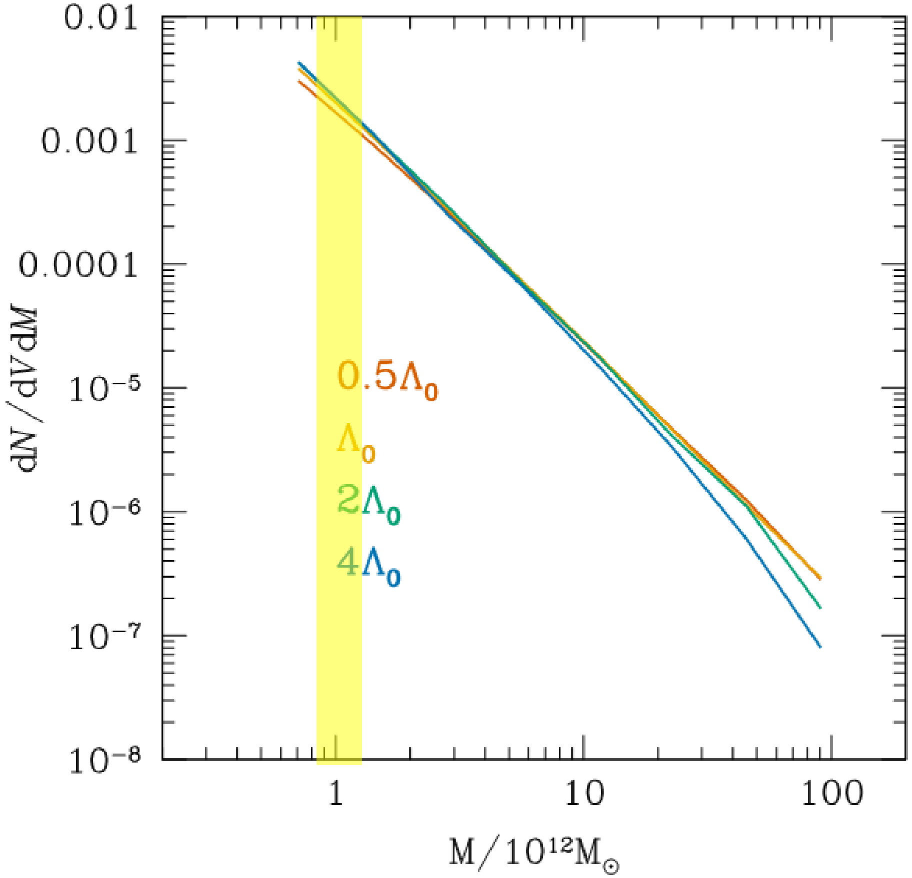
Mass



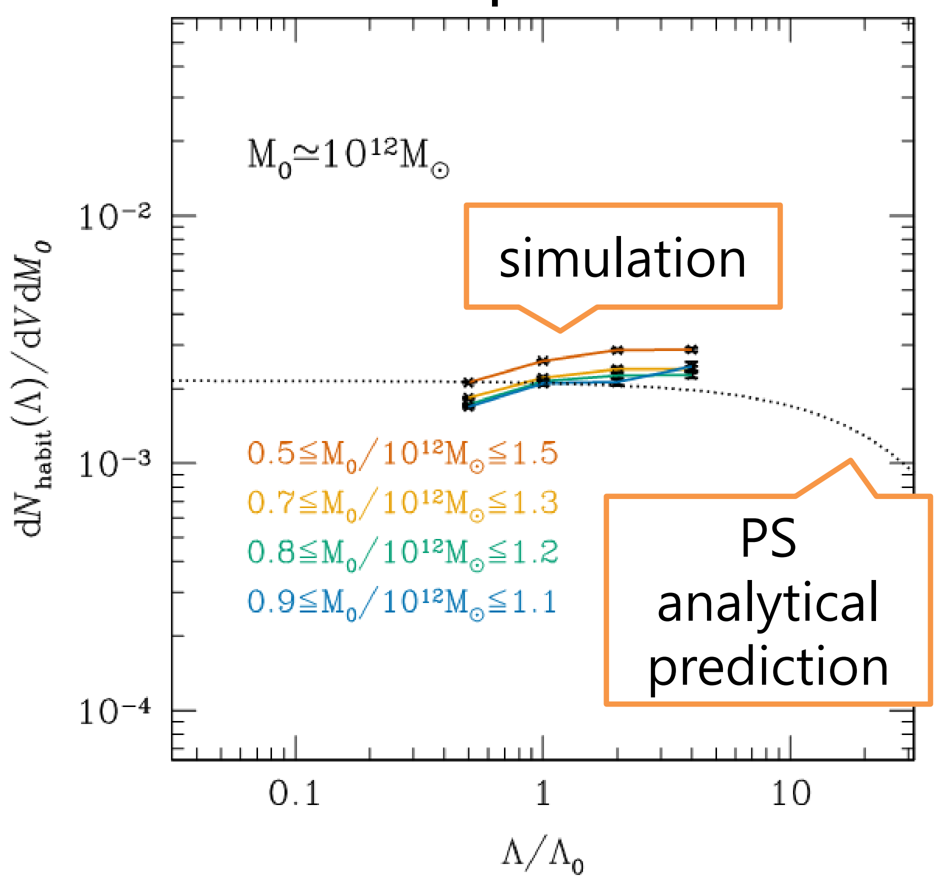
$$0.8 \times 10^{12} \leq M_0/M_{\mathrm{sun}} \leq 1.2 \times 10^{12}$$

Mass

halo mass distribution

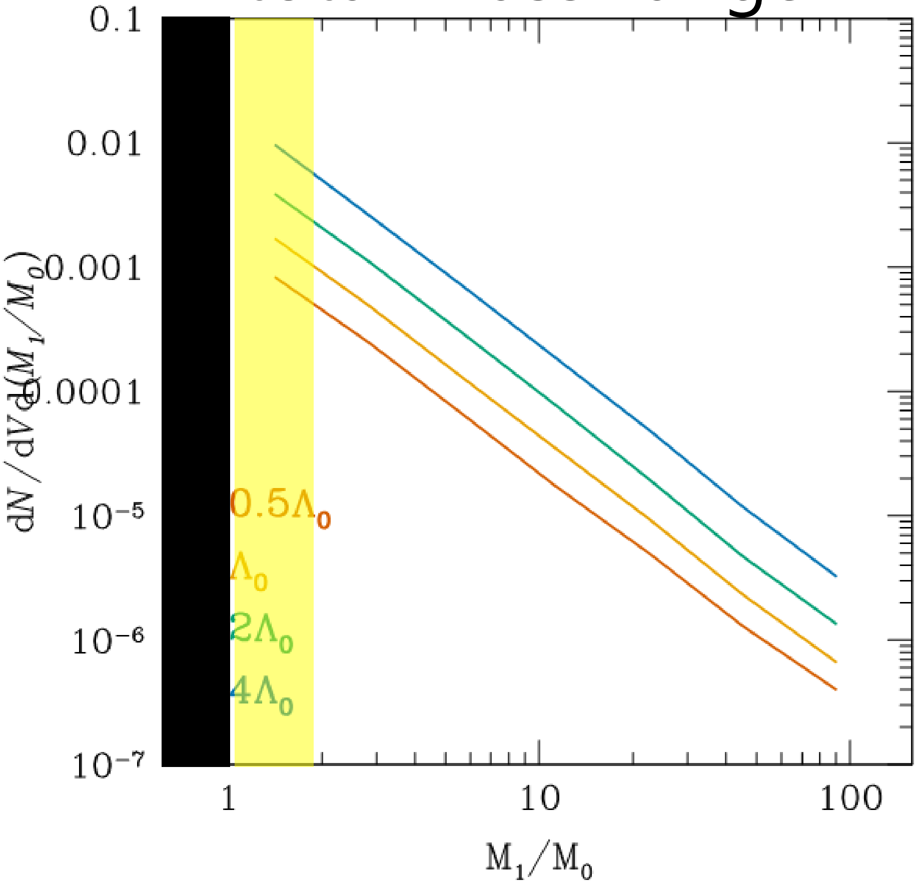


pdf

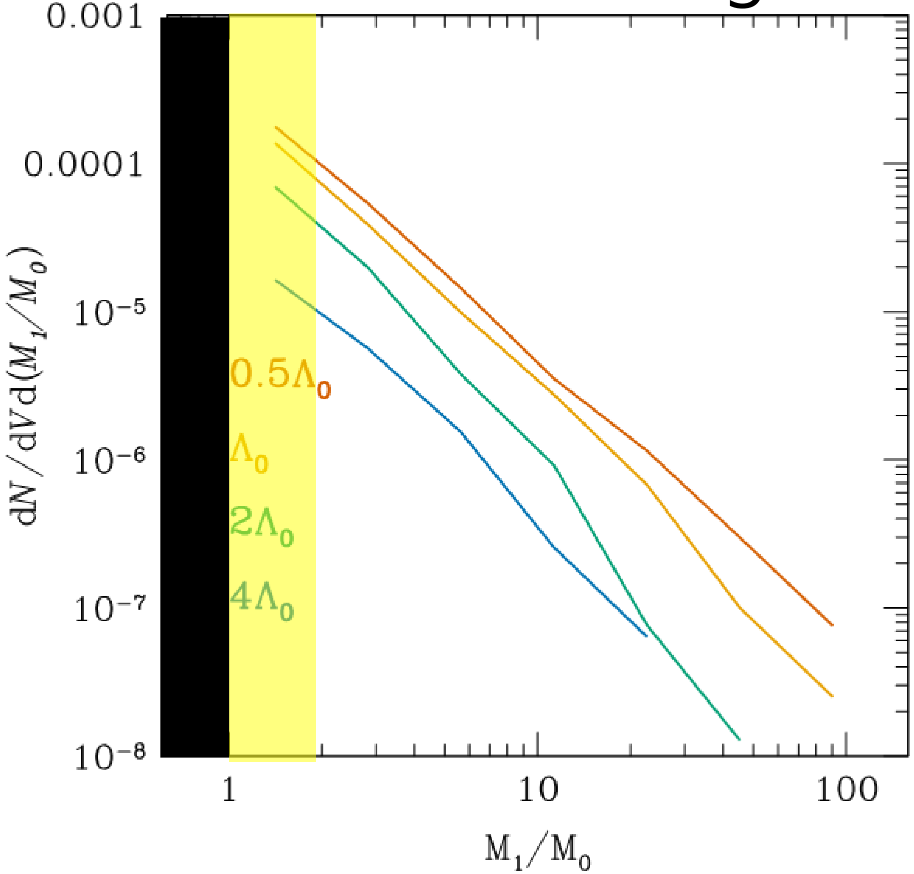


Mass ratio to nearest halo

total mass range

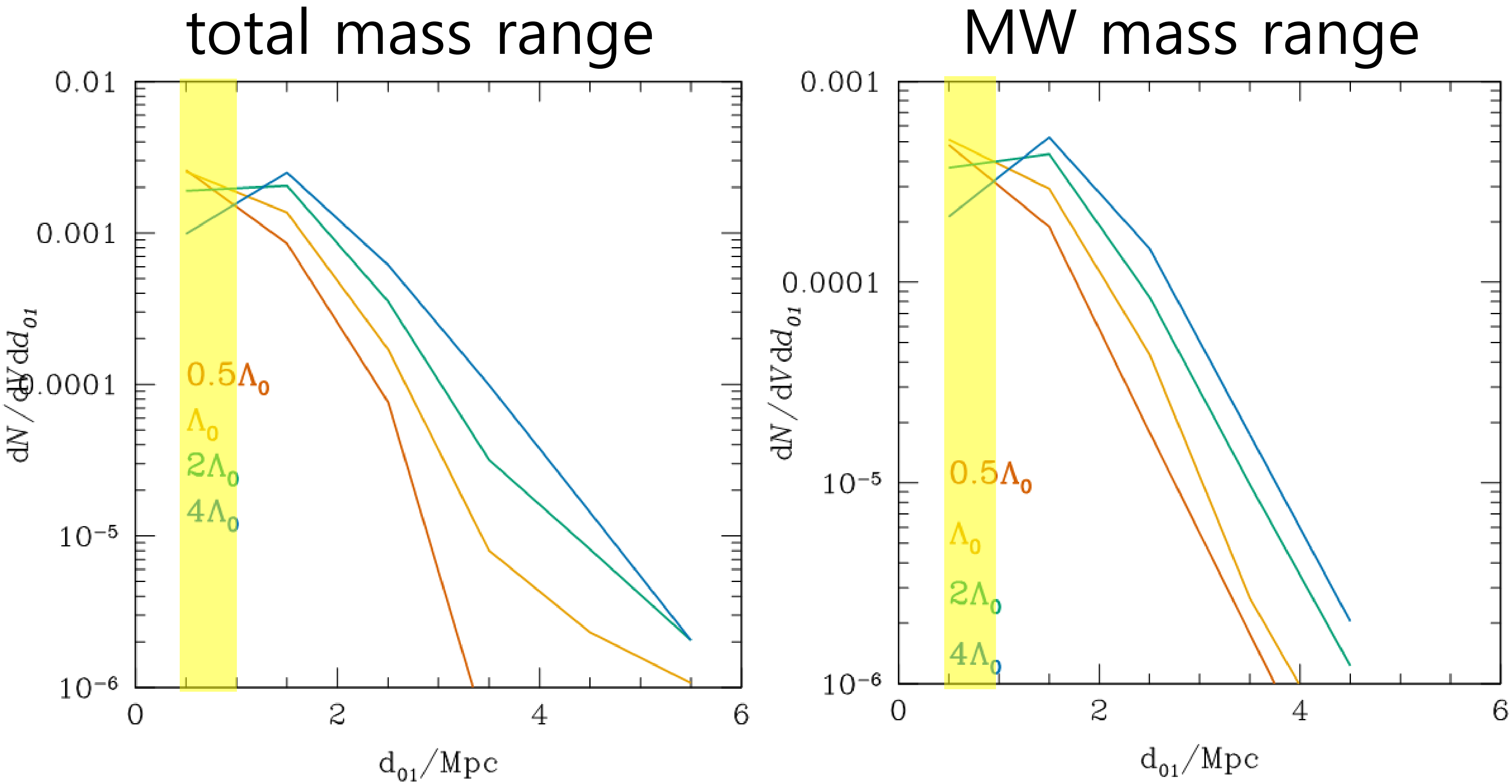


MW mass range



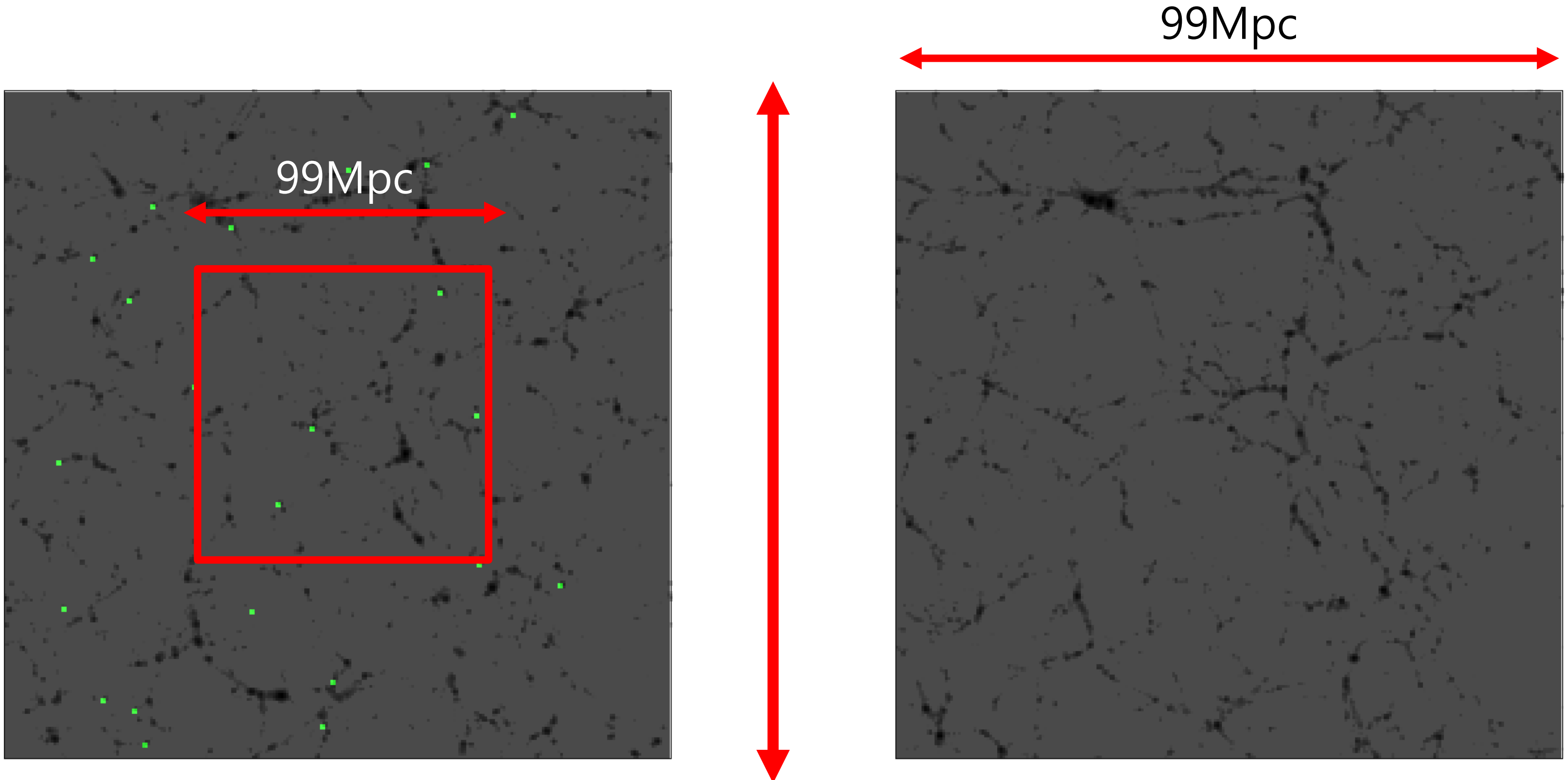
Close halos had already been merged in the large Λ!

Distance to nearest halo



Close halos had already been merged in the large Λ!

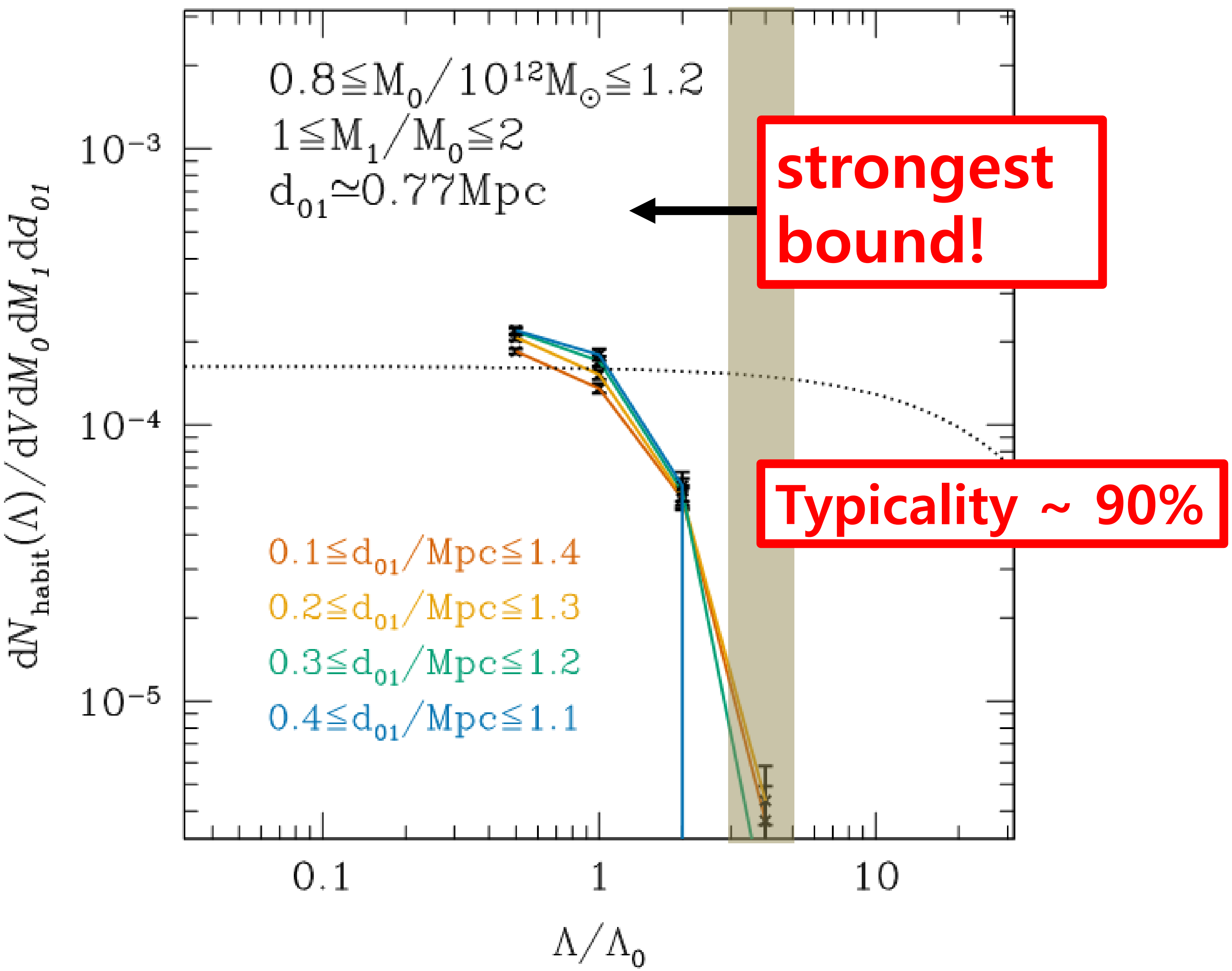
Mass + nearest neighbor



$\Lambda = 0.5\Lambda_0$ $\Lambda = 4\Lambda_0$

128Mpc/h

$$0.8 \times 10^{12} \leq M_0/M_{\text{sun}} \leq 1.2 \times 10^{12}$$
$$1 \leq M_0/M_1 \leq 2$$
$$0.1\text{Mpc} \leq d_{01} \leq 1.4\text{Mpc}$$



0.8≦M0/10^12M⊙≦1.2
1≦M1/M0≦2
d01≃0.77Mpc
strongest bound!
Typicality ~ 90%
0.1≦d01/Mpc≦1.4
0.2≦d01/Mpc≦1.3
0.3≦d01/Mpc≦1.2
0.4≦d01/Mpc≦1.1
10−3
10−4
10−5
0.1
1
10
dNhabit(Λ)/dVdM0dM1dd01
Λ/Λ0

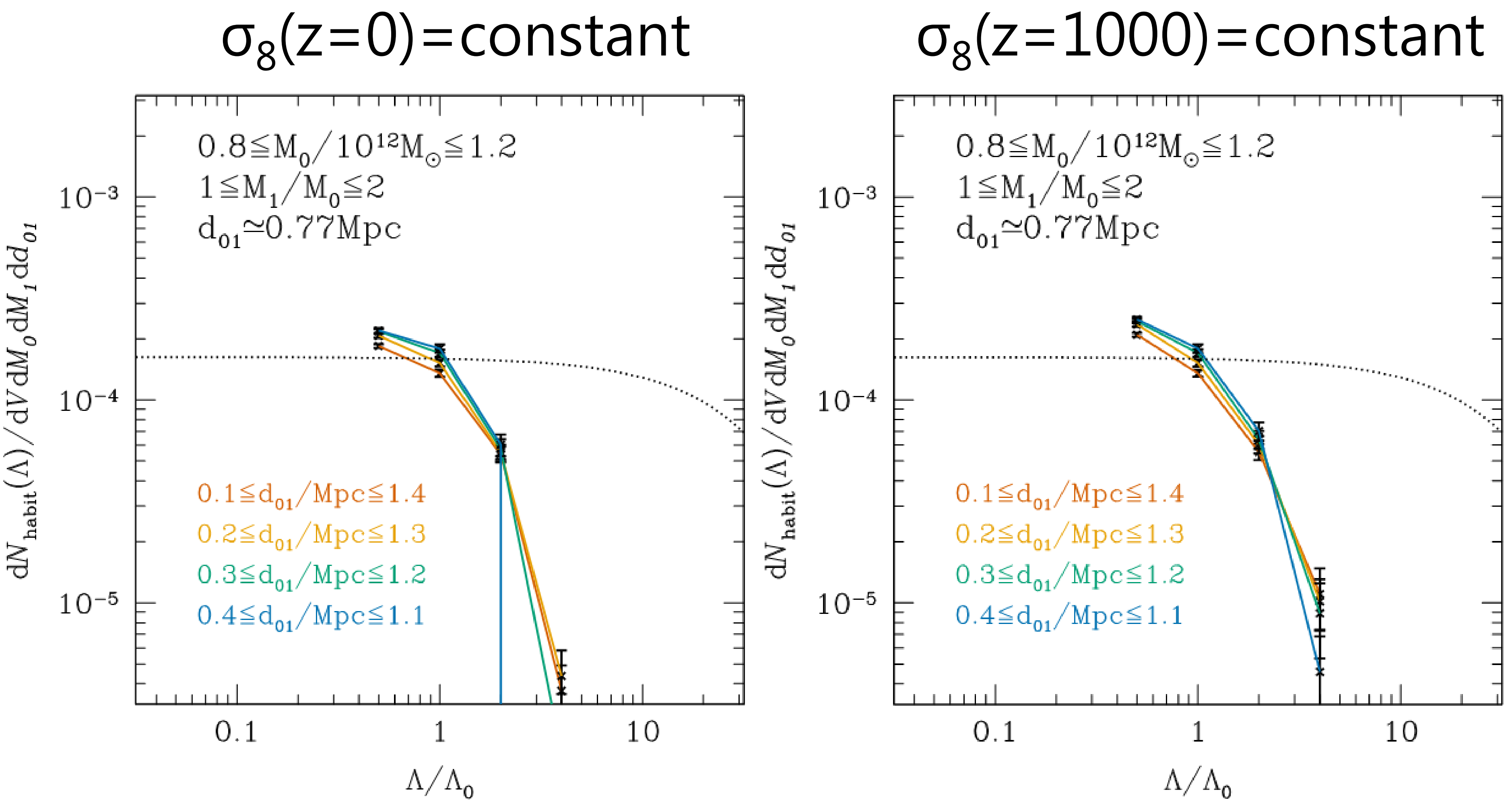
Summary

- We estimated the probability distribution function of the galaxies similar to the Milky Way (mass, distance/mass of neighbor) as a function of the cosmological constant.

- The number of Milky-Way-like galaxies greatly decreases at $\Lambda \sim 3 - 4$, since the structure formation ends early for large Λ

- The typicality of Λ_0 is around 90%, without an assumption of the prior probability

Model dependency



SEH, Changbom Park & Ewan D. Stewart, in preparation