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Statistical Properties of AGNs obtained by a semi-analytic model of galaxy formation

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Abstract

We will report statistical properties of AGNs obtained by a semi-analytic model of galaxy formation, "New Numerical Galaxy Catalogue" (ν^2GC). SMBHs in the model grow by mergers of galaxies and disk instability. We have improved the modelling of the AGN lifetime. We assume that the AGN lifetime is determined not only by the gas supply timescale from their host galaxies but also by the timescale of the angular momentum loss inner 100pc scale, including accretion disks. Although other SA models have not considered the timescale for accretion disks, this would be important for a part of AGNs since theoretically, the timescale becomes longer than that for their host galaxies. We find that the timescale inner 100 pc is important for AGNs whose X-ray luminosities are less than 10^{43} erg/s because such AGNs have a typically smaller mass ratio between the accreted gas mass and BH mass and the gas takes a longer time to lose its angular momentum. In this poster, we will show the AGN luminosity functions in hard X-ray (2-10keV) at $0.0 < z < 5.0$. We will also show the fraction of AGNs which are triggered by mergers of their host galaxies and discuss whether we can observe AGNs after the merging signatures of host galaxies completely disappear.

Introduction

— Constraints on the accretion timescale (previous work)

3-13 × 10^7 yr ($M_{BH} > 10^8$ M_{sun})   ⟨Visible as optical QSOs⟩

In order to reproduce observed optical AGN LFs with $M_B < -22$ at $z \sim 0$ (Kauffmann & Haehnelt 00; KH00)

~ 10^8 yr (Hopkins+ 05)

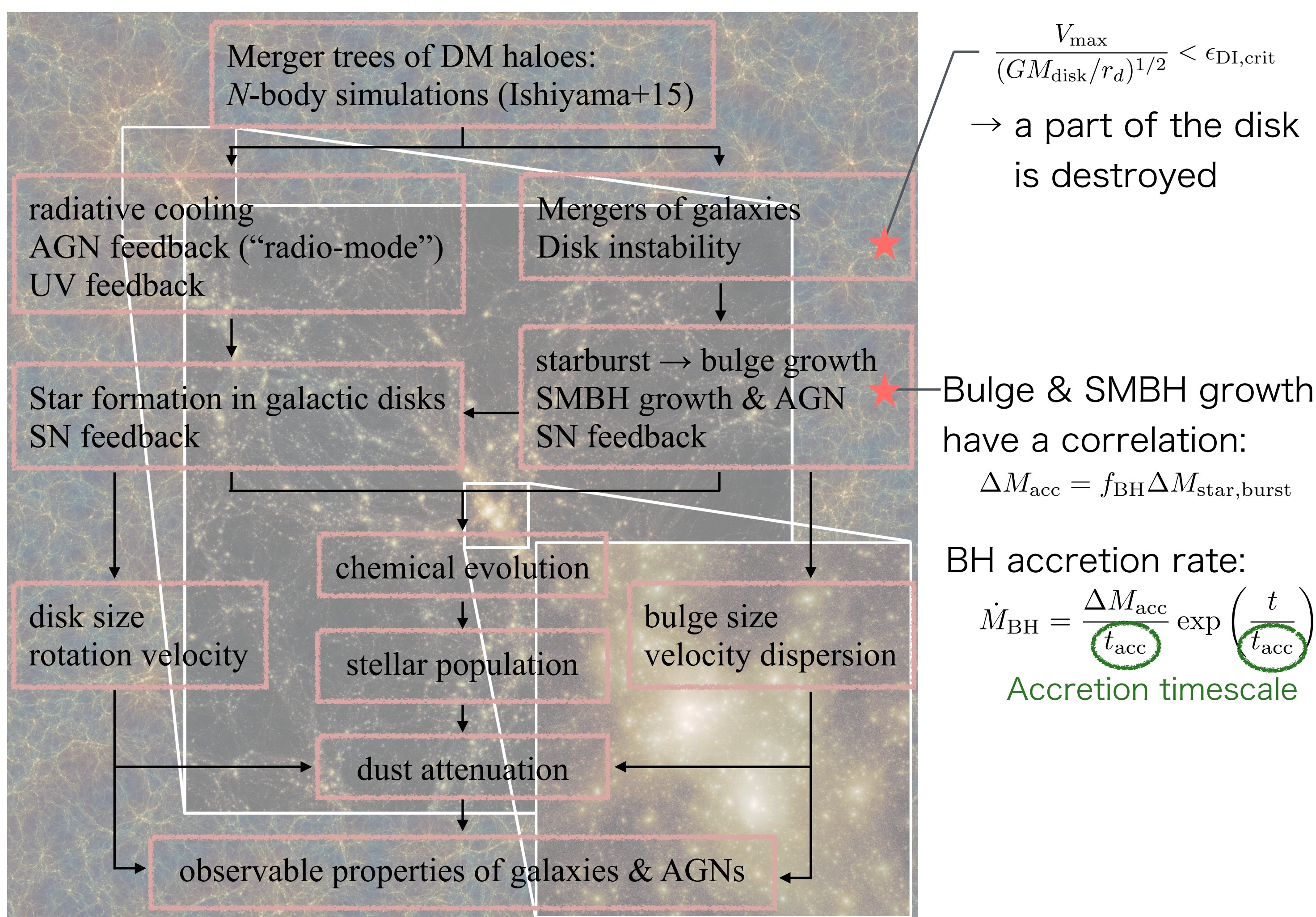More than half of the accretion cannot be observed in optical

These are the same order supported by observational work (e.g., Yo & Tremaine 02). BUT···

— What are important physical mechanisms?
— Accretion timescale of SMBHs with $M_{BH} < 10^8$ M_{sun}?

Properties of Galaxies

We show some of statistical properties of galaxies and SMBHs. Details appear in Shirakata+ in prep. (probably submitted in this year!)

K-band LFs M_{BH}-M_{bulge} M_K-V_{bulge} M_K-r_{bulge} H_I MF @ z~0

Results

We show AGN LFs in hard X-ray (2-10 keV) at $0 < z < 5$.

Model A.   **Model B.**

Model A&B: Reproduce AGN LFs @ L_X (2-10keV) > 10^{44} erg/s

To reproduce the faint end···
- More AGNs are induced by other mechanisms
     OR
- Accretion timescale need some modifications

→ Model C can explain the faint end of AGN LFs!

⟨The timescale is consistent with previous work (~10^{7-8} yr)⟩

$M_B < -23.2$

Model A
Model B

Model C.

> 60% of faint AGNs are induced by minor mergers
→ Difficult to observe merger evidence···

Semi - Analytic Model of Galaxy Formation

We employ an updated version of an SA model "*New Numerical Galaxy Catalogue (ν^2GC)*" based on Makiya+16.

Merger trees of DM haloes: N-body simulations (Ishiyama+15)

$\frac{V_{max}}{(GM_{disk}/r_d)^{1/2}} < \epsilon_{DI,crit}$

→ a part of the disk is destroyed

radiative cooling
AGN feedback ("radio-mode")
UV feedback

Mergers of galaxies
Disk instability

Star formation in galactic disks
SN feedback

starburst → bulge growth
SMBH growth & AGN
SN feedback

Bulge & SMBH growth have a correlation:

$\Delta M_{acc} = f_{BH} \Delta M_{star,burst}$

BH accretion rate:

$\dot{M}_{BH} = \frac{\Delta M_{acc}}{t_{acc}} \exp\left(\frac{t}{t_{acc}}\right)$

Accretion timescale

disk size
rotation velocity

chemical evolution

stellar population

bulge size
velocity dispersion

dust attenuation

observable properties of galaxies & AGNs

Image: http://hpc.imit.chiba-u.jp/~nngc/gallery.html

Accretion timescale: We test three models of t_{acc}.

Model A. $t_{acc} = 0.03(1+z)^{-1/5}$ Gyr   ($t_{acc} \propto t_{dyn,halo}$; KH00)

Model B. $t_{acc} = \alpha_{bulge} t_{dyn,bulge}$

Model C. $t_{acc} = \alpha_{bulge} t_{dyn,bulge} + t_{loss}$

⟨An empirical model considering angular momentum loss <100 pc
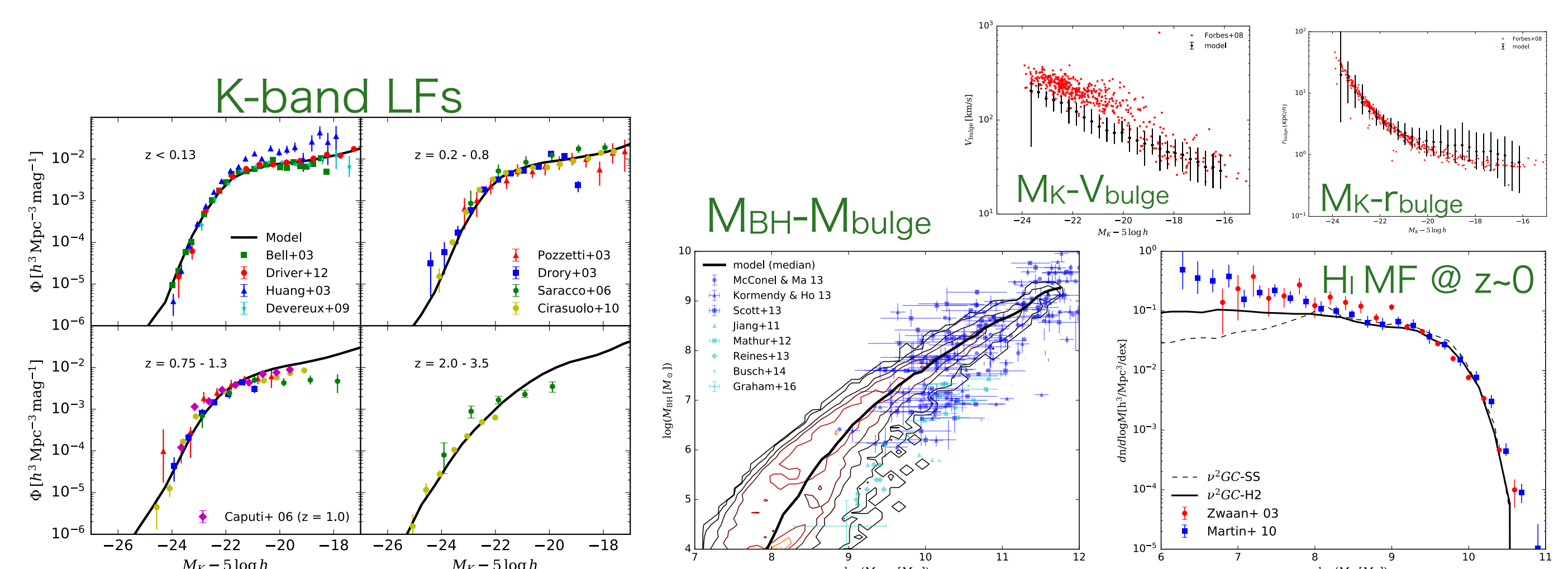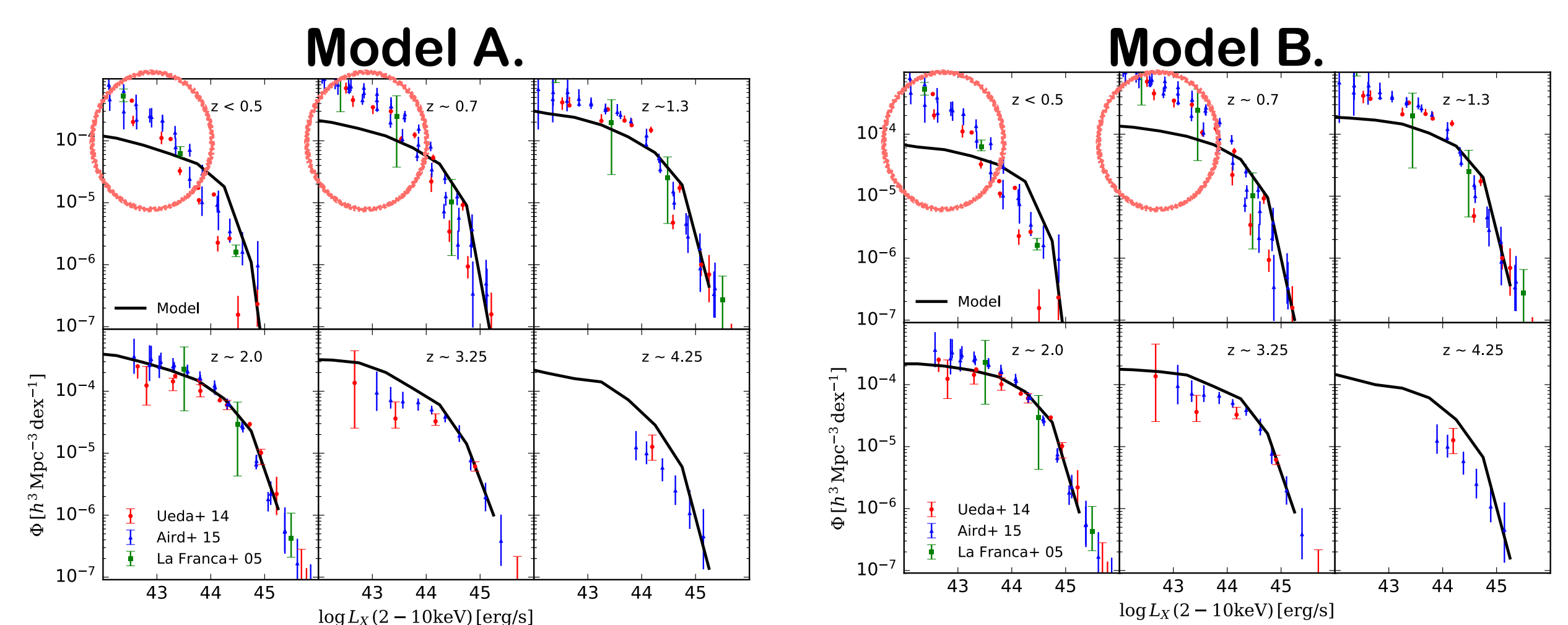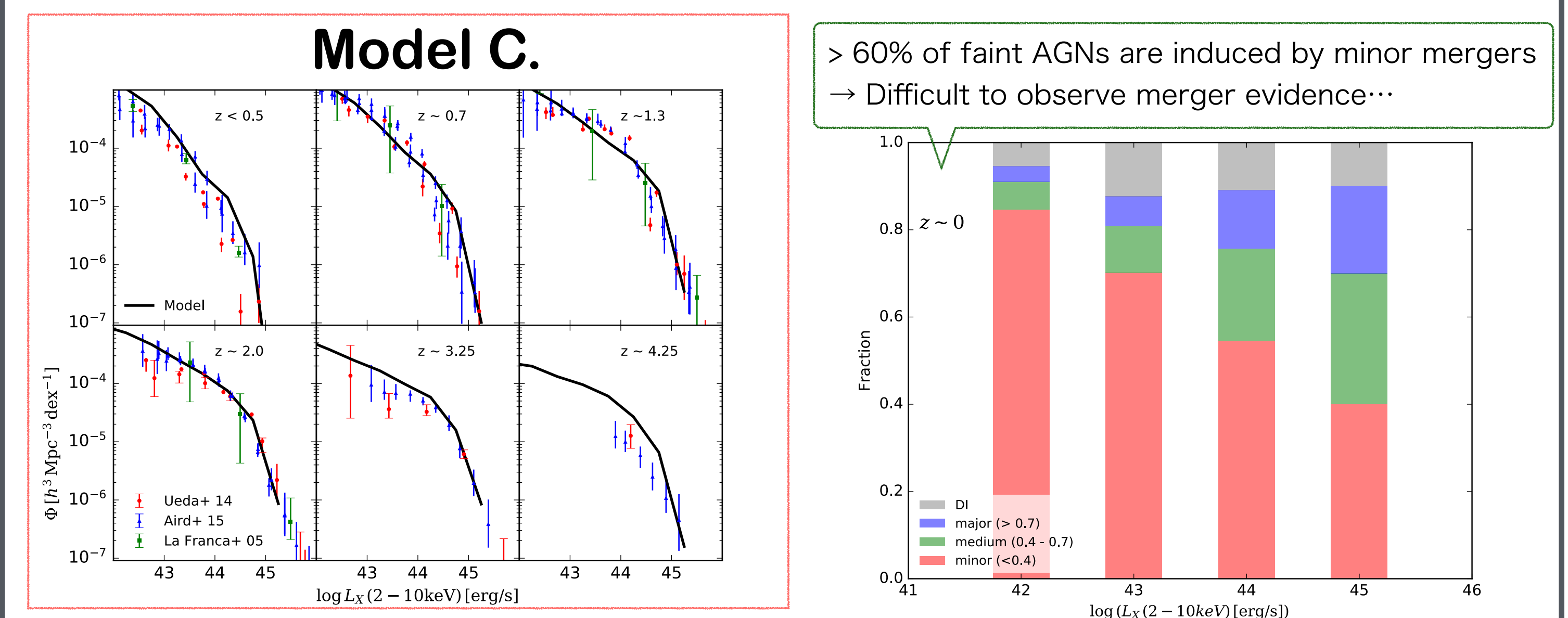
$t_{loss} = t_{loss,0} M_{BH}^{3.5} \Delta M_{acc}^{-4.0}$⟩

AGN luminosity:

$\dot{M}_{BH} \rightarrow L_{bol}$ $\frac{L_{bol}}{L_{Edd}} = 1/(1/(1 + 3.5(1 + \tanh(\log(\dot{m}/\dot{m}_{crit})))) + \dot{m}_{crit}/\dot{m})$ ($\dot{m} = \dot{M}_{BH}/\dot{M}_{Edd}$)

(Kawaguchi 03)

$L_{bol} \rightarrow L_X(2-10\text{keV})$ bolometric correction obtained by Marconi+04

Reference

Hopkins et al. (2005), ApJL, 625, L71
Ishiyama T. et al. (2015), PASJ, 67, 61
Kauffmann & Haehnelt (2000), MNRAS, 311, 576
Kawaguchi (2003), ApJ, 593, 69
Makiya R. et al. (2016), PASJ, 68, 25
Marconi et al. (2004), MNRAS, 351, 69

ν^2GC data is available!
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