初代星初代銀河研究会 in 鹿児島

初代銀河形成

に関するいくつかの話題

吉田直紀 (東大理/IPMU)

鹿児島で研究会

郷中教育が日本を拓いた

「議を言うな」一薩摩の青少年の間では、暗黙のうちに、このような取り決めがなされていました。「つべこべ小賢しい理屈を言わず、先輩の言うことには従え。」ということです。藩政時代、薩摩では、城下の居住地をいくつかの区域に分け、その区域ごとで子弟の教育にあたりました。区域のひとつひとつを「方限」とか「郷」と呼び、その教育機関として、郷の相中、略して「郷中」、つまり現在の学区にあたる制度を設けたのです。

郷中では、幼少の頃から肉体的にも精神的にも徹底した鍛練教育が行なわれ、特に上下関係は厳しくしつけられました。「議を言うな」「長老衆には従え」という暗黙の了解は、そう 培われたものと思われます。薩摩藩には幕末 33 の郷中があり、中でも下加治屋町郷中 荒田の三郷中（三方限）と並んで、幕末から明治にかけて多くの逸材を生み出したこと 偉人傑士として、西郷隆盛や大久保利通、西郷従道、大山巌、村田新八、東郷平八 他を輩出し、郷中教育が日本近代化への

和田さんLOC
ありがとうございます

Kagoshima's "Goju" educati

"Do as you're told and don't argue" was the rule among Satsuma youths under the shimadzu.

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- ✦ **Supersonic baryonic motions**
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References:

Naoz, NY Gnedin, 2011, 2013, ApJ

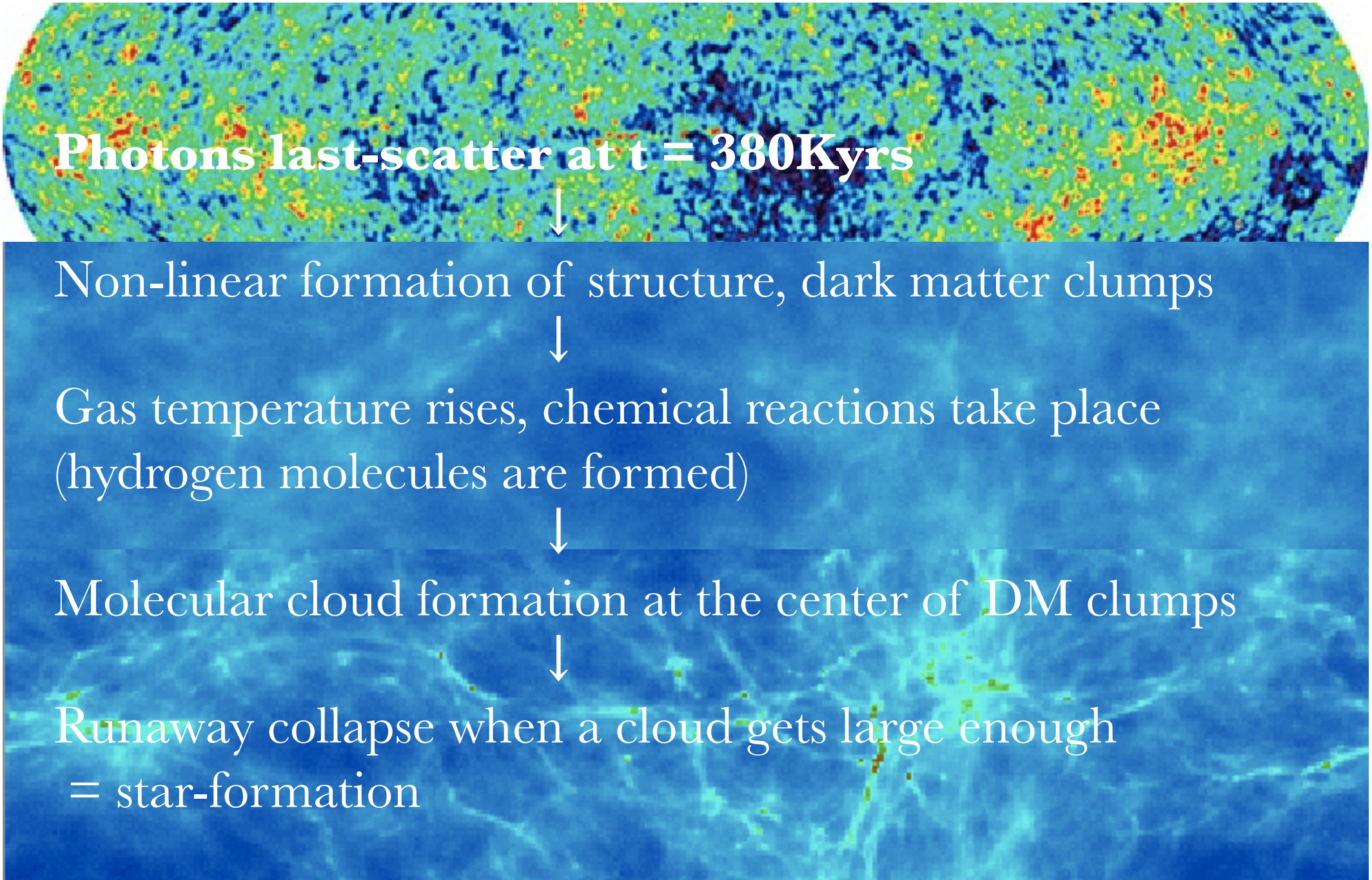
Inoue et al. 2014, ApJ

Shimizu et al. 2014 MNRAS

Hosokawa, Yorke, Omukai, Inayoshi, NY, 2013, ApJ

Tanaka, Moriya, NY, 2013, MNRAS

STAR-FORMATION IN THE EARLY UNIVERSE



Photons last-scatter at t = 380Kyrs

↓

Non-linear formation of structure, dark matter clumps

↓

Gas temperature rises, chemical reactions take place (hydrogen molecules are formed)

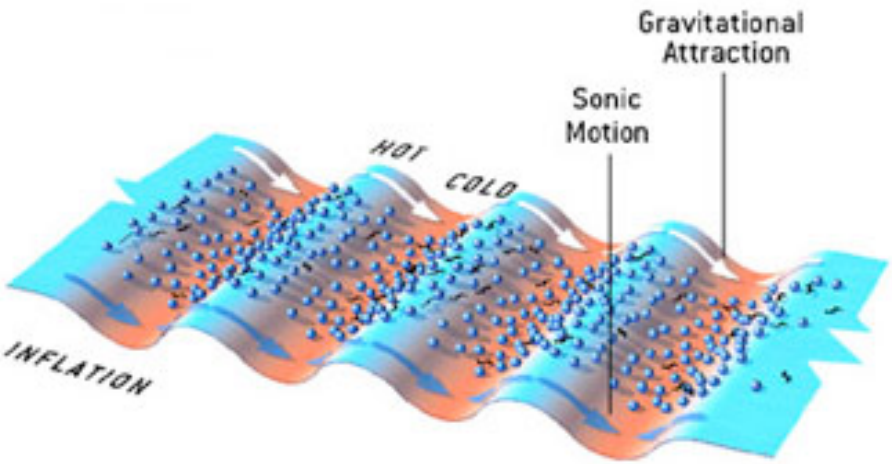
↓

Molecular cloud formation at the center of DM clumps

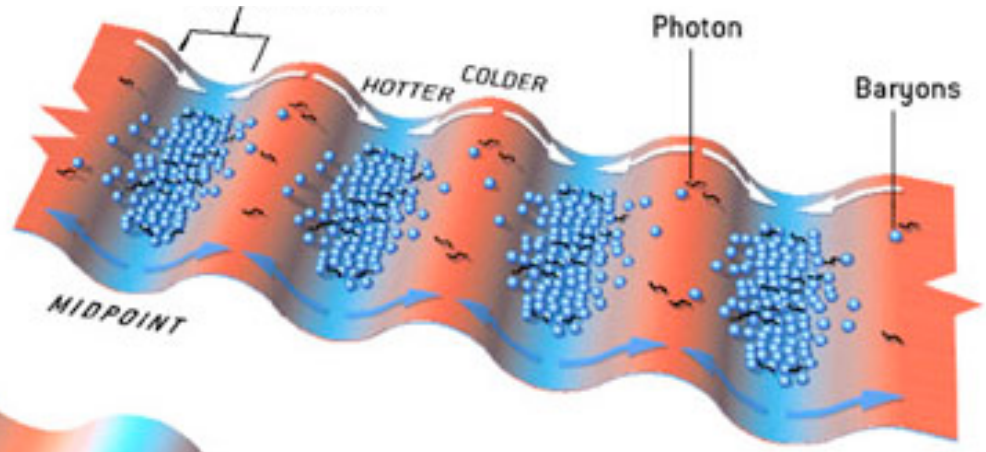
↓

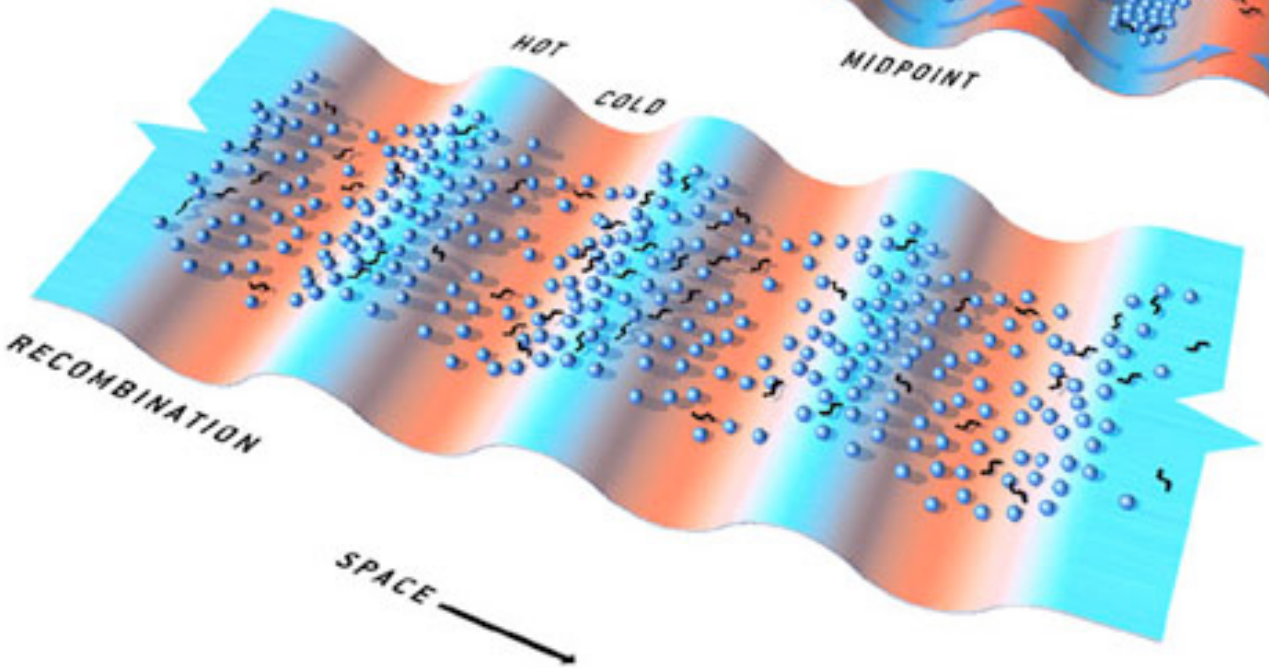
Runaway collapse when a cloud gets large enough = star-formation

初期宇宙のバリオン振動



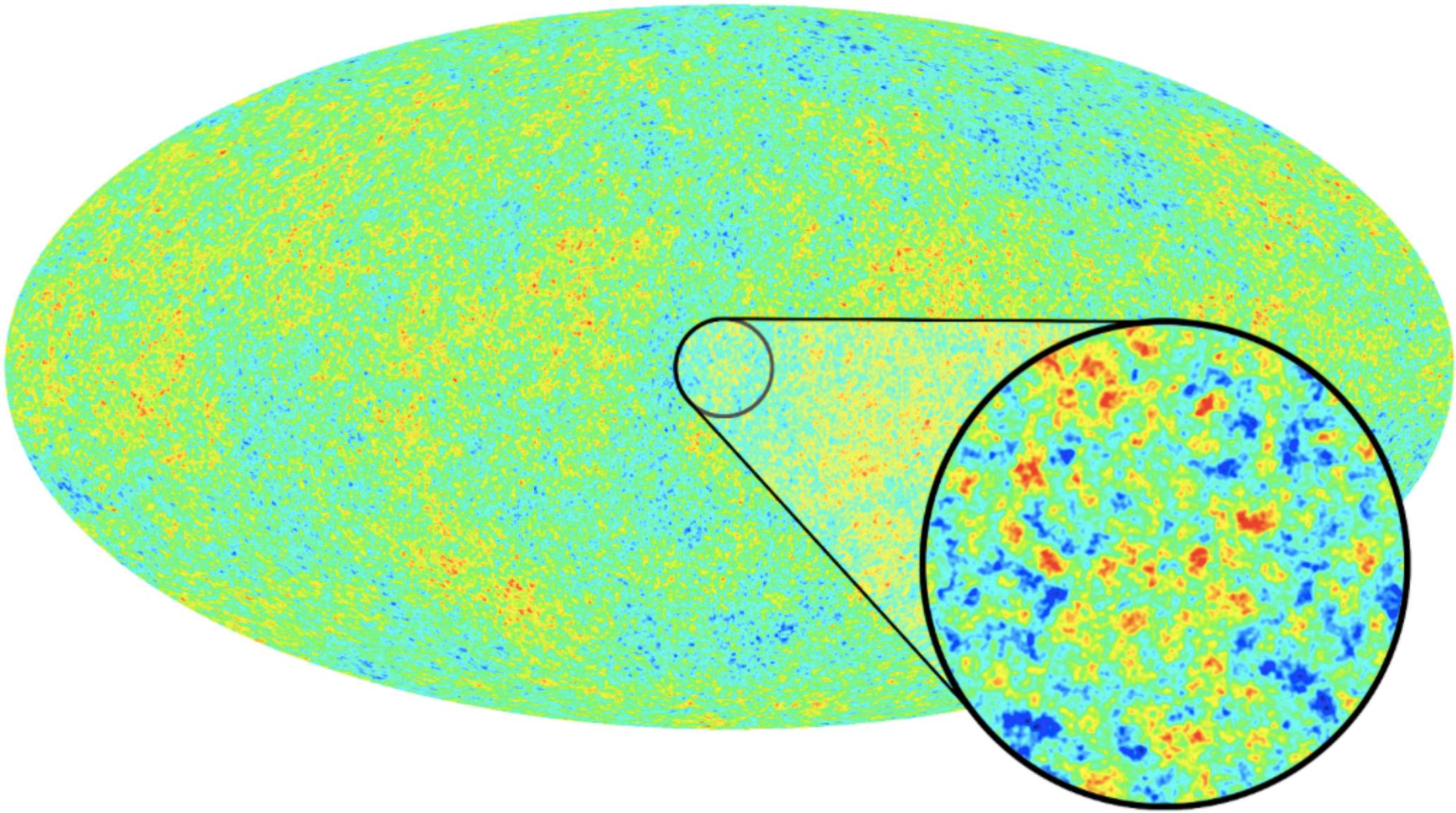
ダークマターの重力ポテンシャル





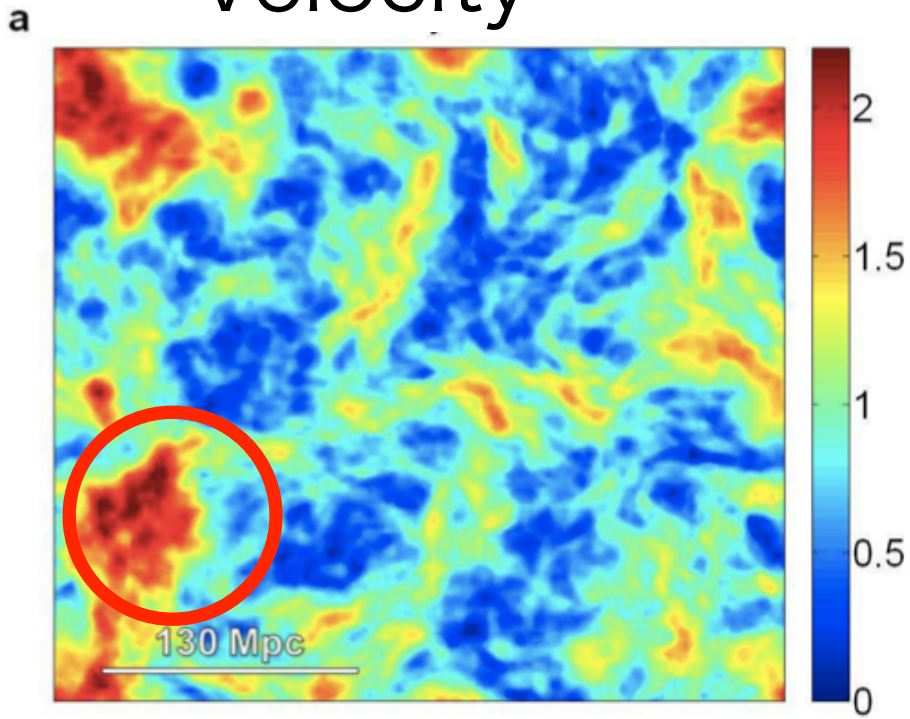
光子バリオン流体

CMB温度揺らぎ

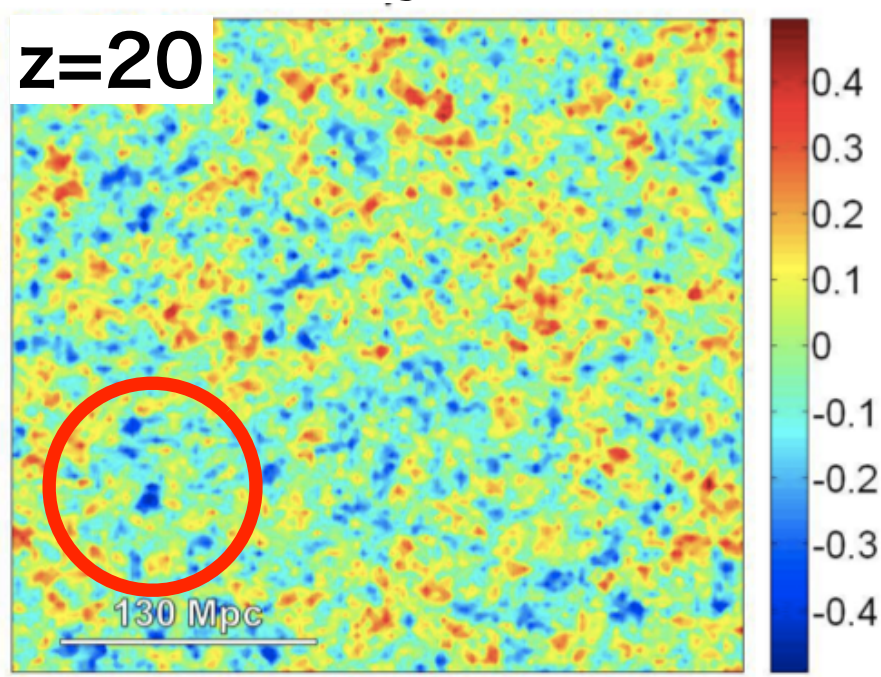


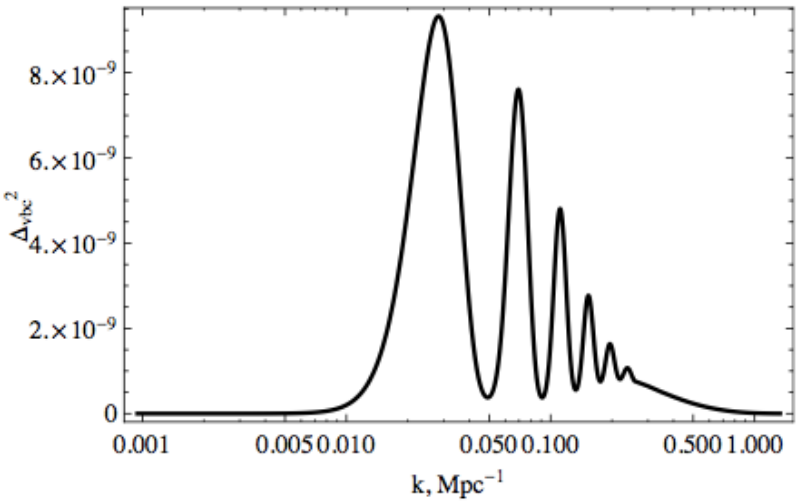
Supersonic stream

Velocity



Density



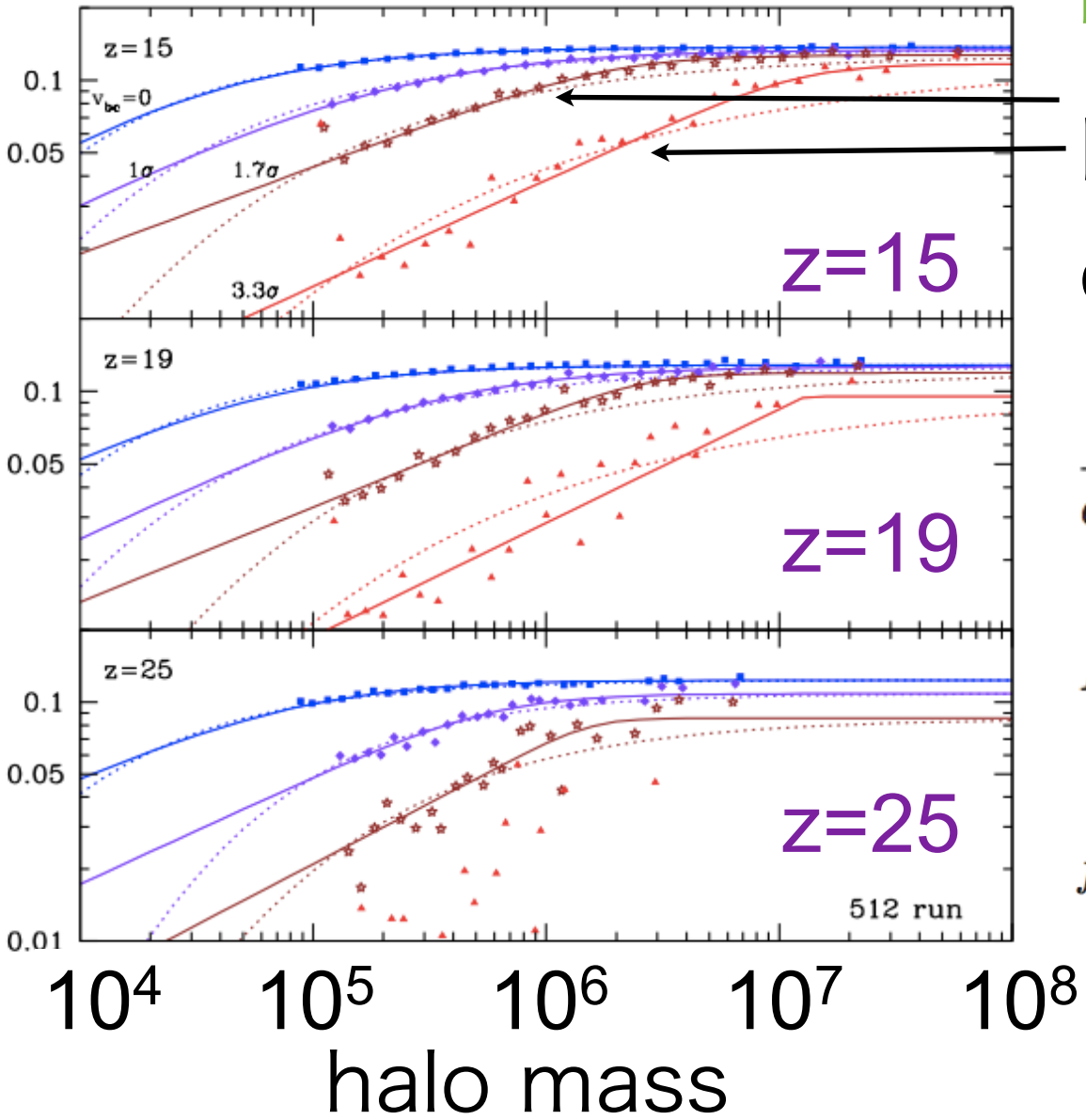


Relative motions between gas and dark matter

Tseliakhovich & Hirata 2011; Visbal+ 12; Maio+ 12

Effect on early structure

Gas fraction



Naoz, NY, Gnedin 2011;2013

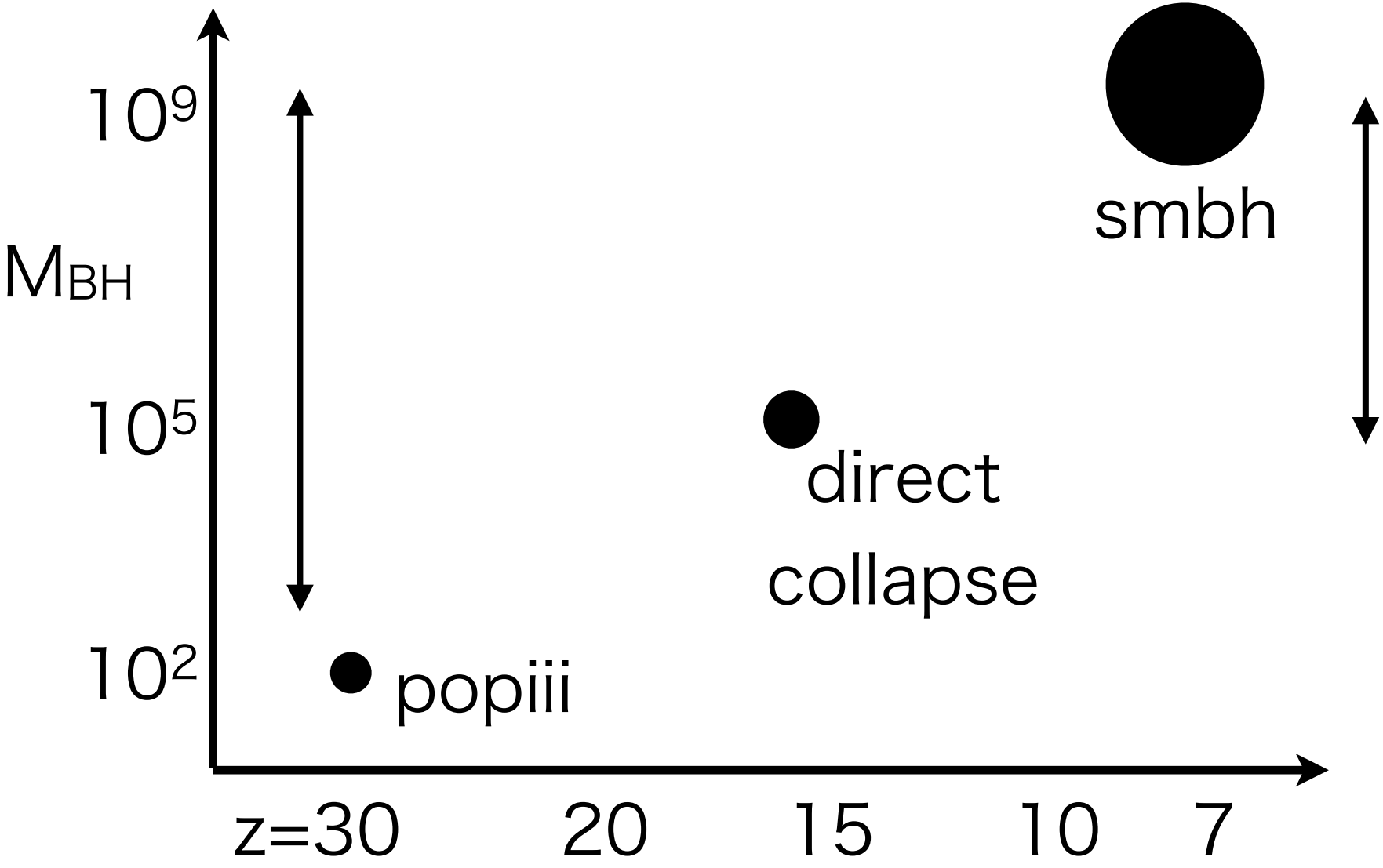
Filtering mass description

$$\frac{\delta_{\rm b}}{\delta_{\rm tot}} = 1 - \frac{k^2}{k_F^2} + r_{\rm LSS}$$

$$M_F = \frac{4\pi}{3}\bar{\rho}_0 \left(\frac{1}{2}\frac{2\pi}{k_F}\right)^3$$

$$f_{g,\rm calc} = f_{\rm b,0}\left[1 + (2^\gamma - 1)\left(\frac{M_c}{M}\right)^\beta\right]^{-1/\gamma}$$

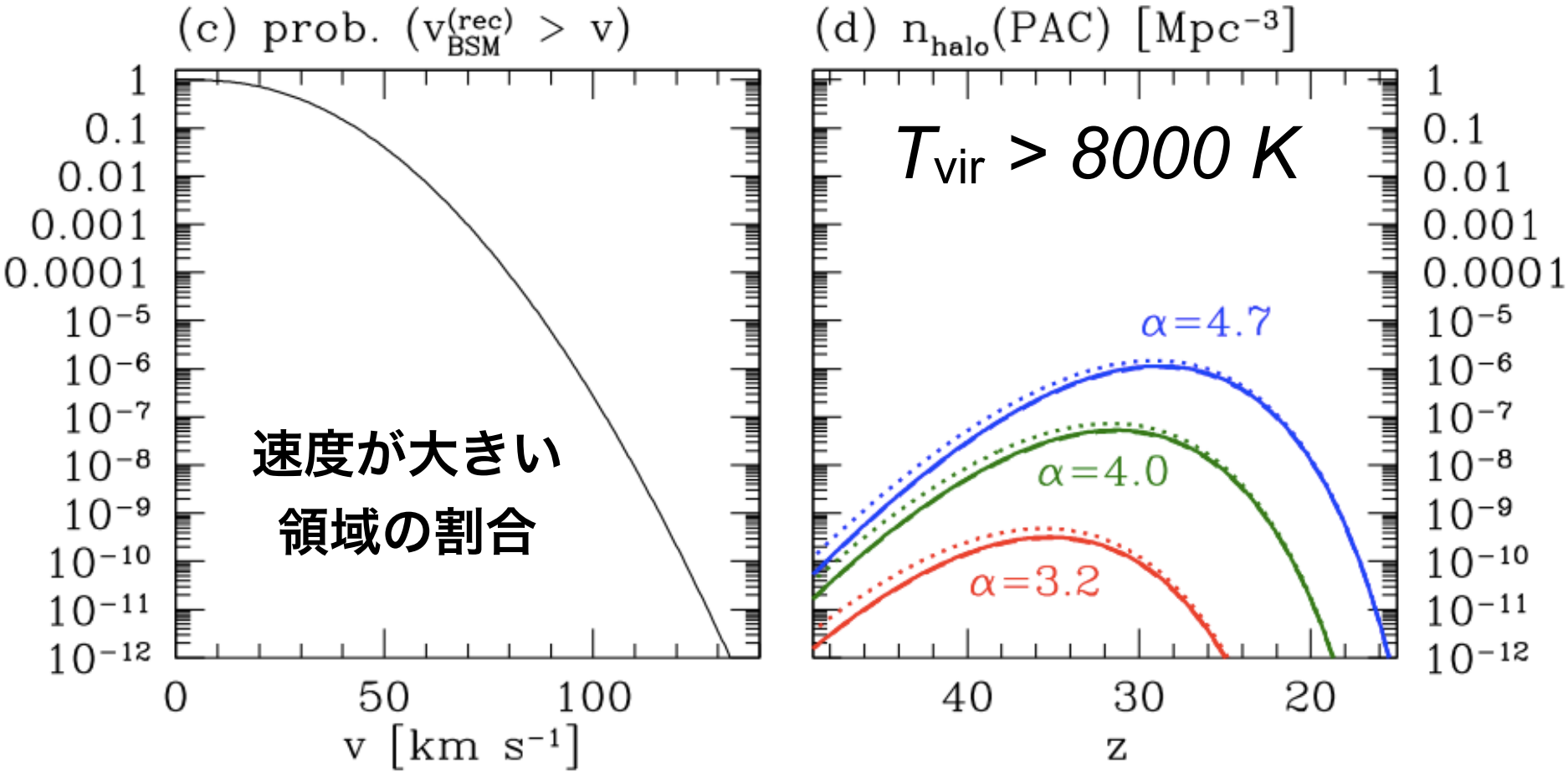
SMBH growth



Effect on BH growth

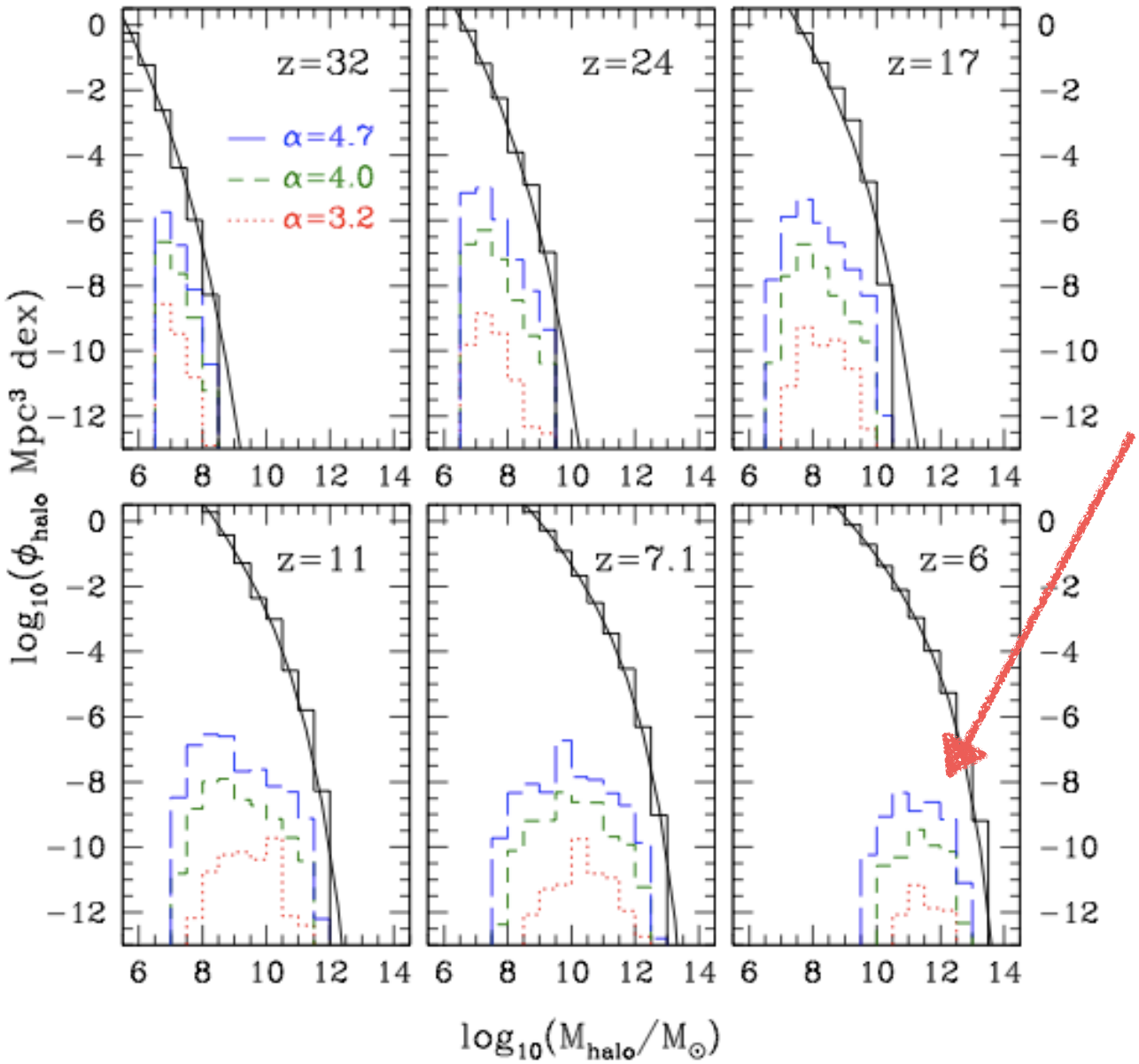
$$v_{\rm cool} = \sqrt{v_0^2 + [\alpha\, v_{\rm BSM}(z)]^2}$$

v_0 ~ 3-4 km/s



Tanaka & Li 2014

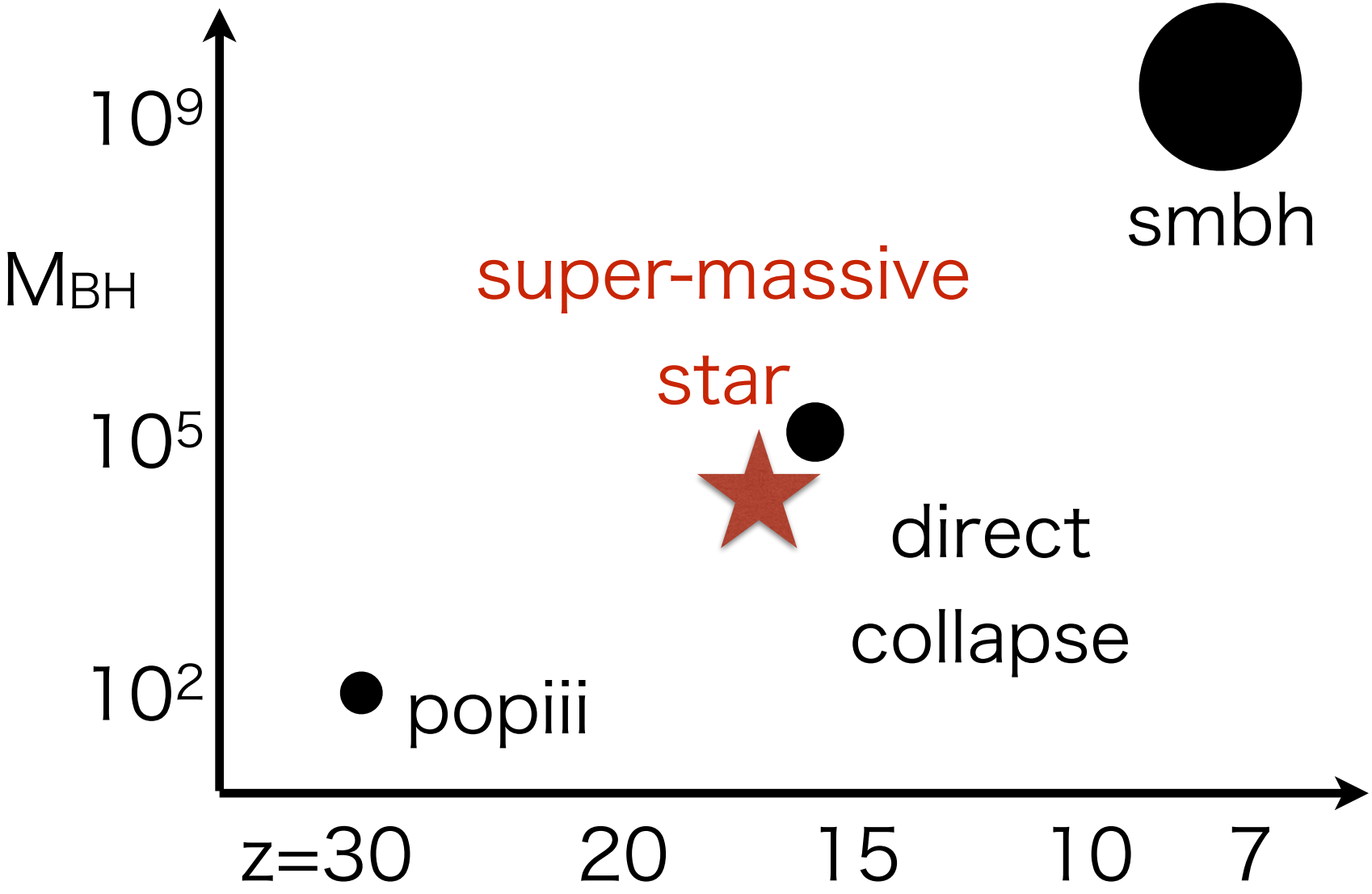
Effect on BH growth



Comoving number density of BHs from a merger tree simulation

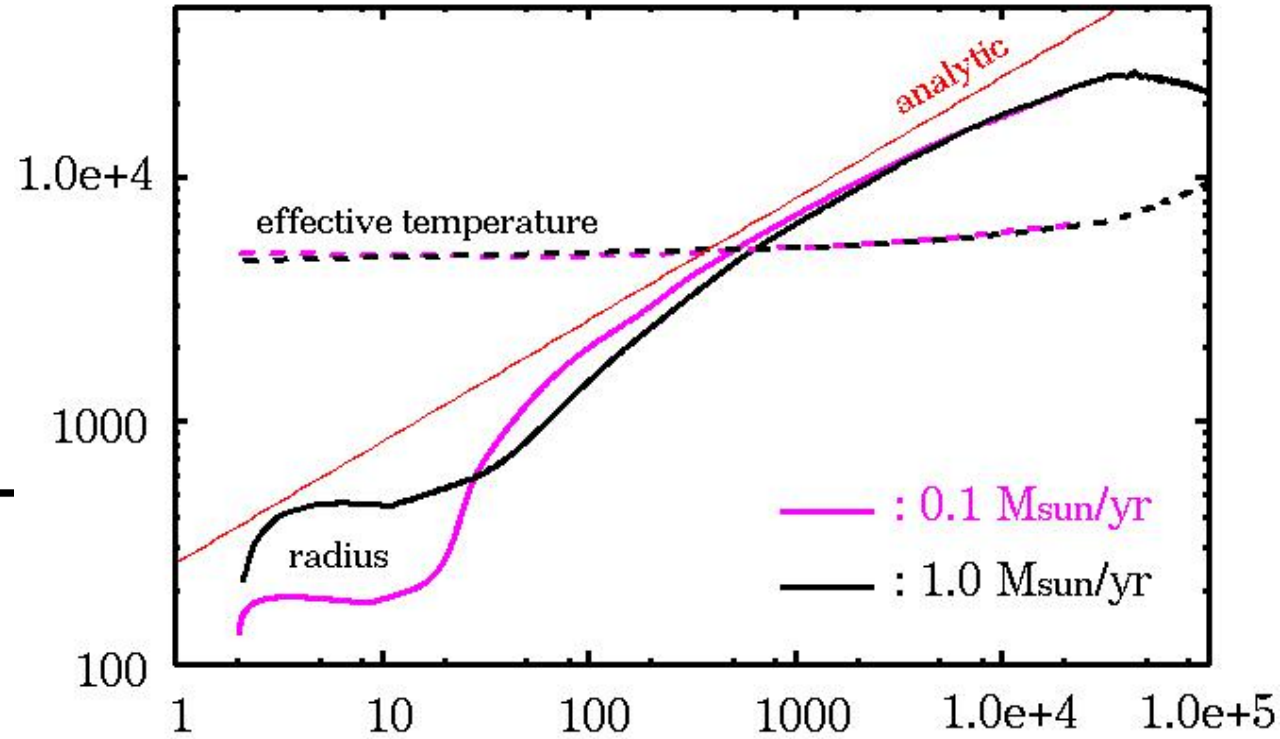
Tanaka & Li 2014

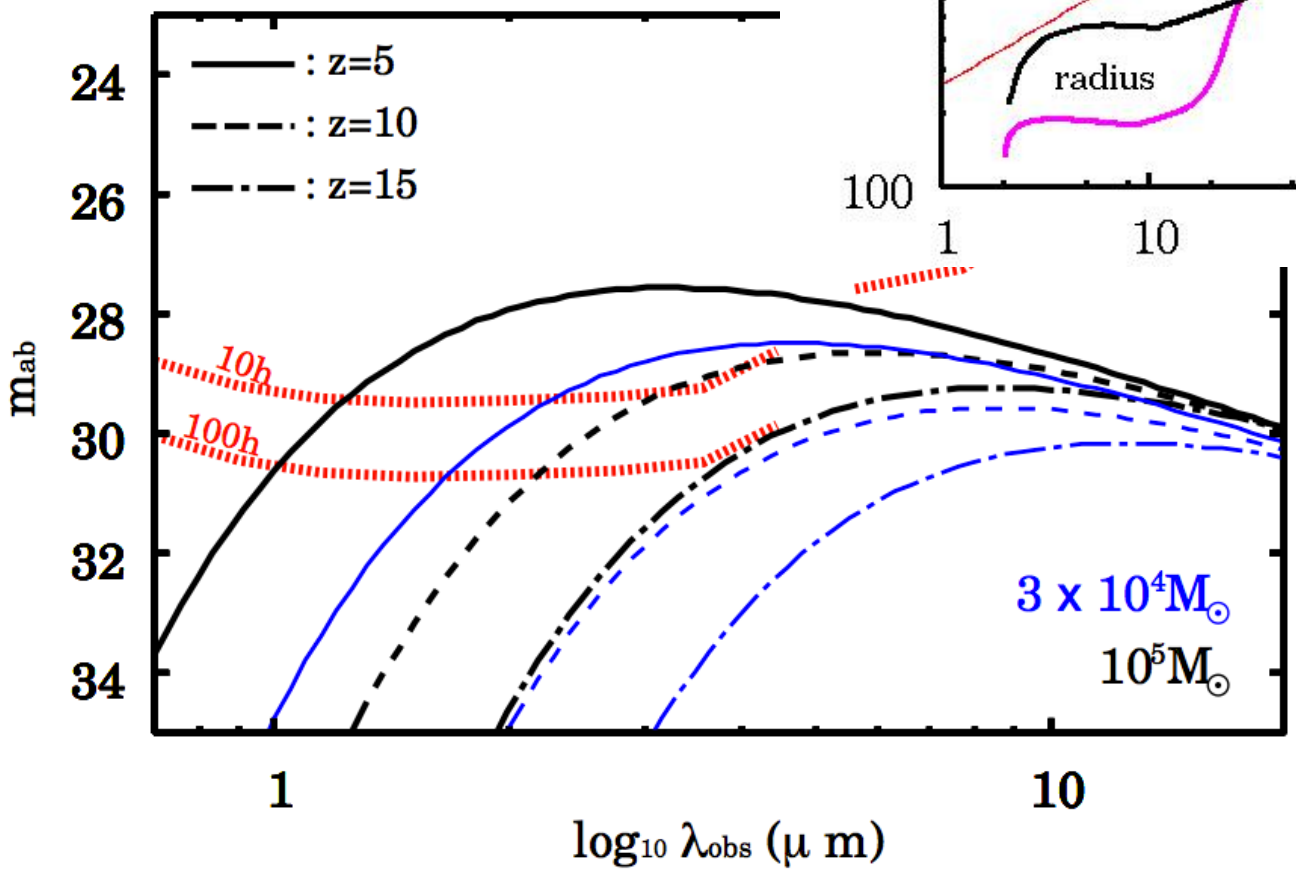
SMBH growth


10^9
M_{BH}
10^5
10^2
smbh
super-massive
star
direct
collapse
popiii
z=30
20
15
10
7

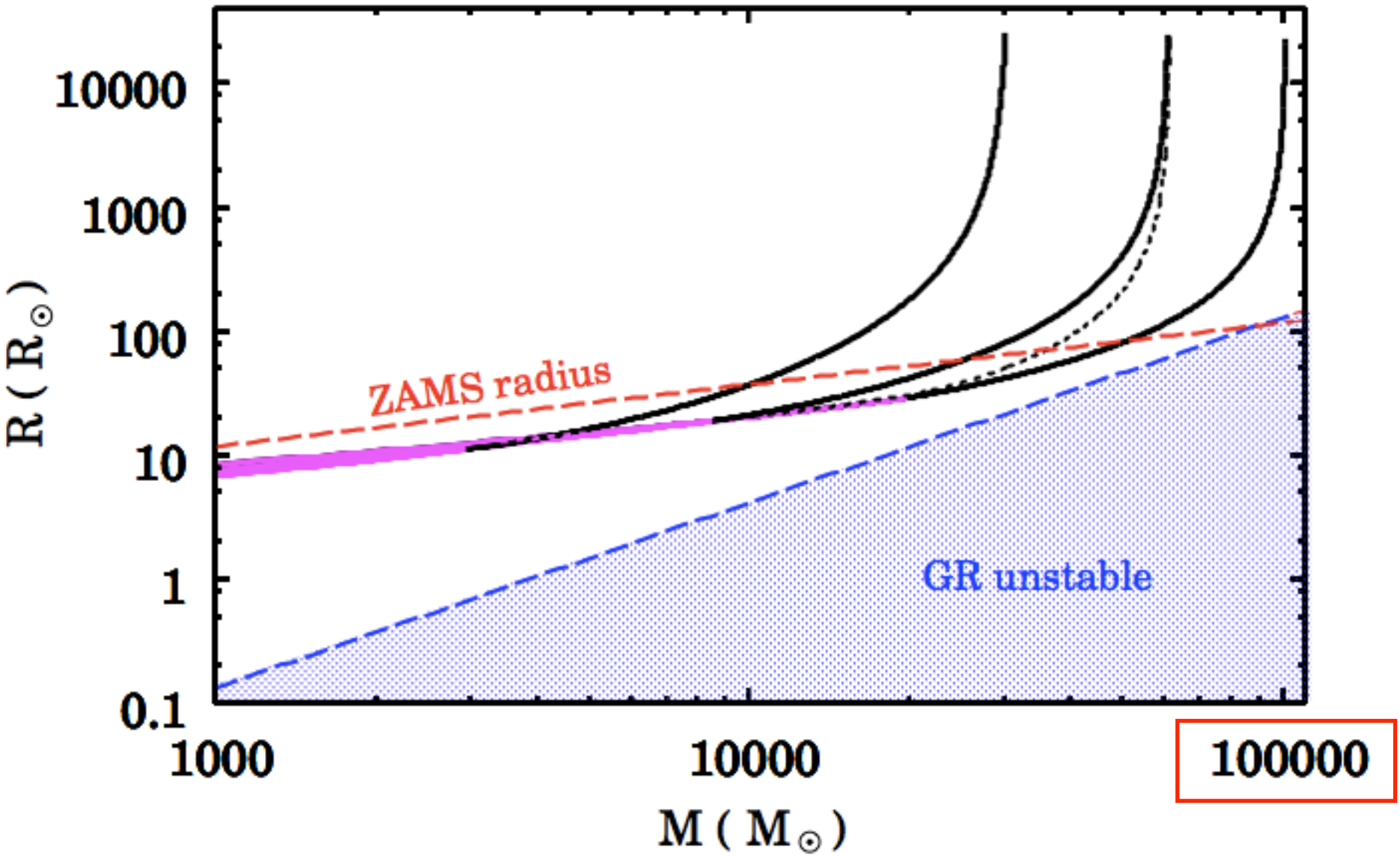
Supermassive star in IR

By T. Hosokawa





本当に重力崩壊するか

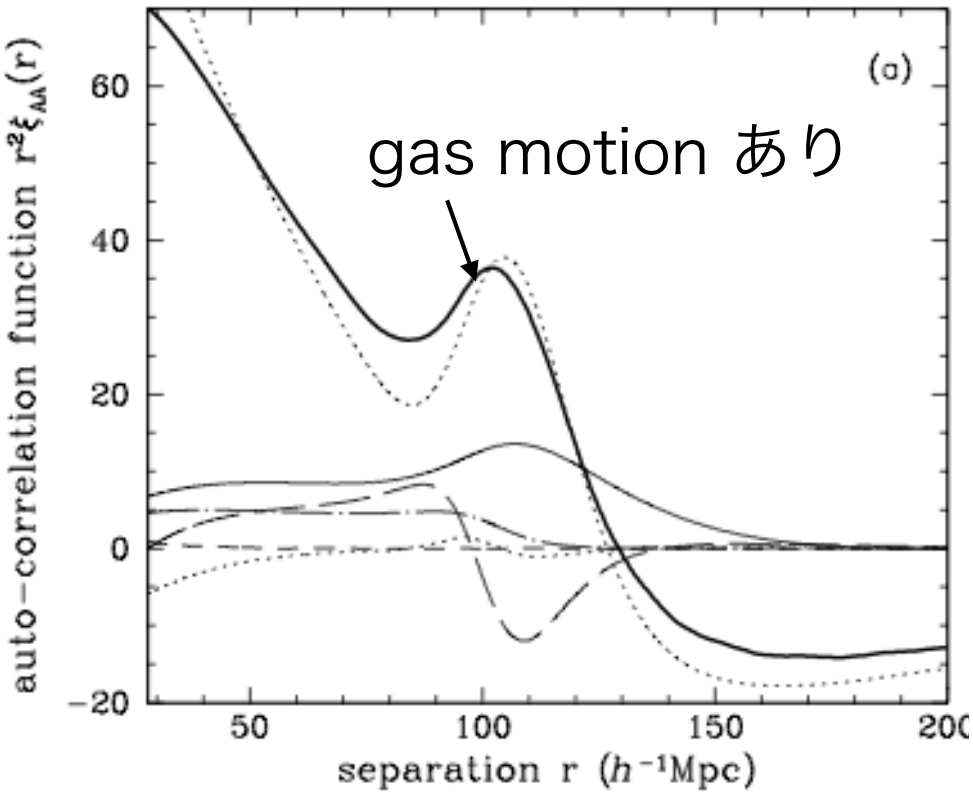

10000
1000
100
10
1
0.1
R (R⊙)
ZAMS radius
GR unstable
1000
10000
100000
M (M⊙)

Supersonic motions おまけ

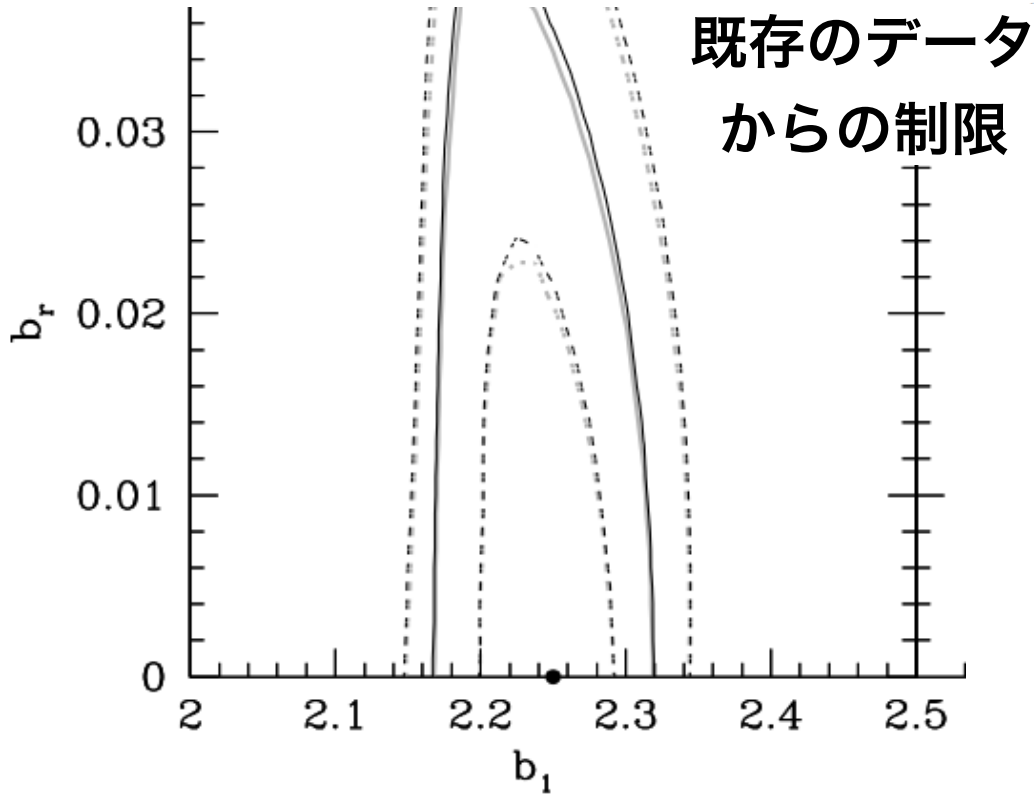
Effect on galaxy clustering

宇宙論の人が泣いてよろこぶBAOのピークが”ずれる”

$$P_g(\mathbf{k}) = b_1^2\, P_{\rm NL}(\mathbf{k}) + \int \frac{d^3\mathbf{q}}{(2\pi)^3} P_m(q) P_m(|\mathbf{k}-\mathbf{q}|) \Big[\frac{1}{2}\, b_2^2 + 2\, b_1 b_2 F_2(\mathbf{q}, \mathbf{k}-\mathbf{q})$$
$$+4\, b_1 b_r F_2(\mathbf{q}, \mathbf{k}-\mathbf{q}) G_u(\mathbf{q}, \mathbf{k}-\mathbf{q}) + 2\, b_2 b_r G_u(\mathbf{q}, \mathbf{k}-\mathbf{q}) + 2\, b_r^2 G_u(\mathbf{q}, \mathbf{k}-\mathbf{q})^2 \Big]$$



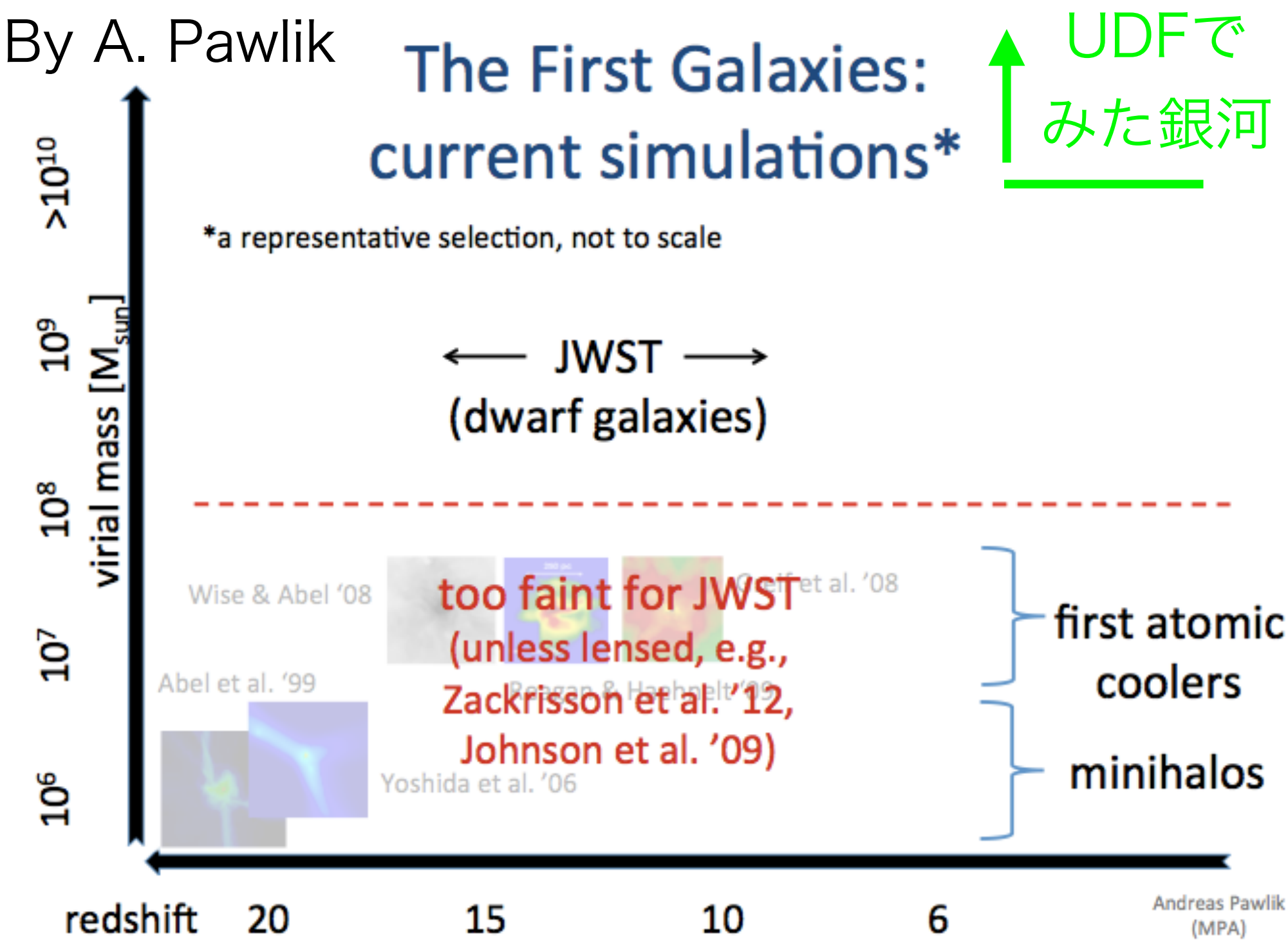
$$\delta_g(\mathbf{x}) = b_1\, \delta_m(\mathbf{x}) + \frac{b_2}{2}\, \left[\delta_m^2(\mathbf{x}) - \sigma_m^2\right] + b_r\, \left[u_r^2(\mathbf{x}) - \sigma_{u_r}^2\right]$$



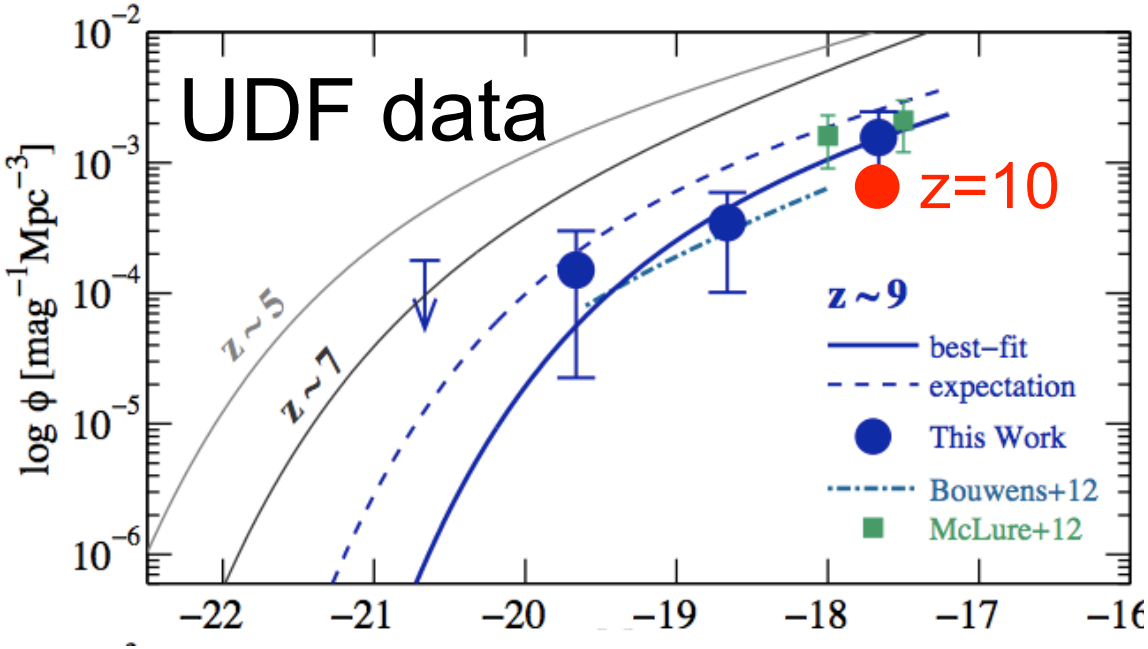
Yoo & Seljak 2014

High-z galaxies

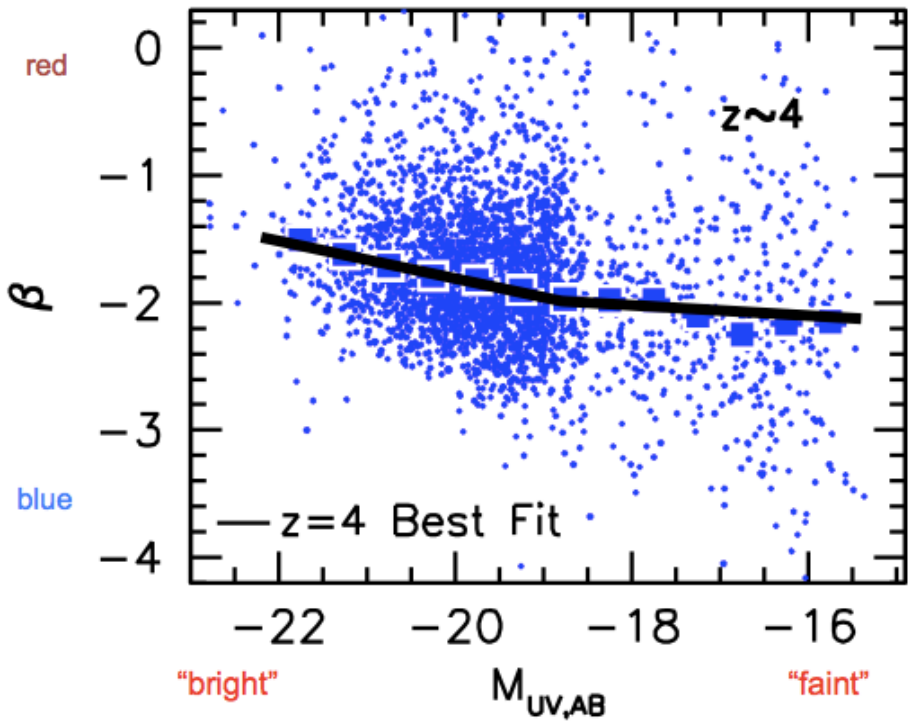
By A. Pawlik


The First Galaxies:
current simulations*
UDFで
みた銀河
*a representative selection, not to scale
virial mass [M_{sun}]
$>10^{10}$
10^9
10^8
10^7
10^6
← JWST →
(dwarf galaxies)
Wise & Abel '08
Abel et al. '99
Yoshida et al. '06
too faint for JWST
(unless lensed, e.g.,
Zackrisson et al. '12,
Johnson et al. '09)
first atomic
coolers
minihalos
redshift
20
15
10
6
Andreas Pawlik
(MPA)

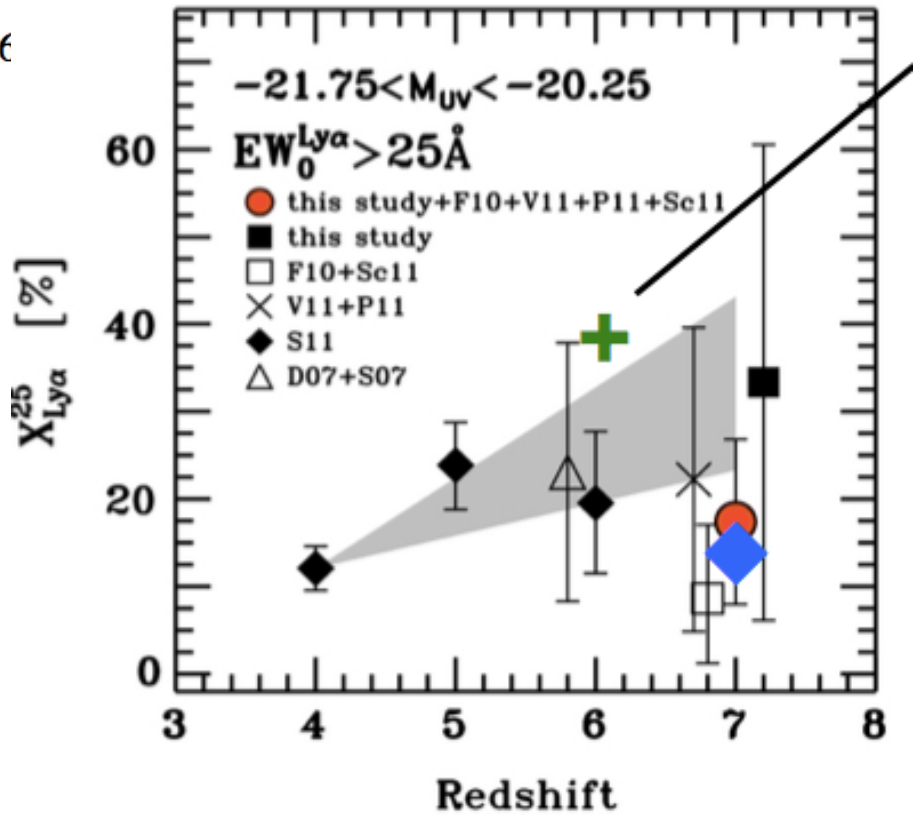
Observed galaxies



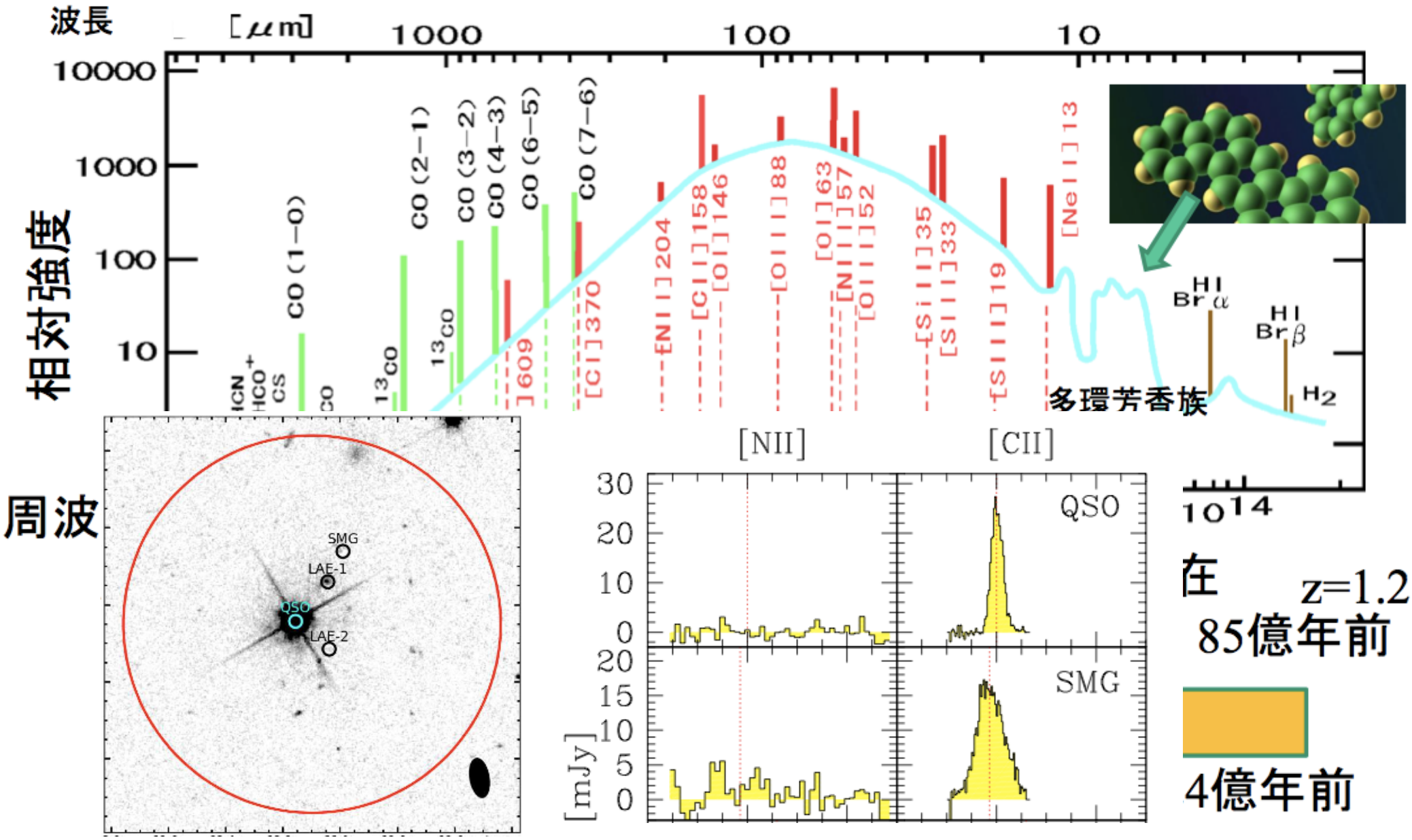
Number density evolution,
then luminosity evolution at z>8 ?



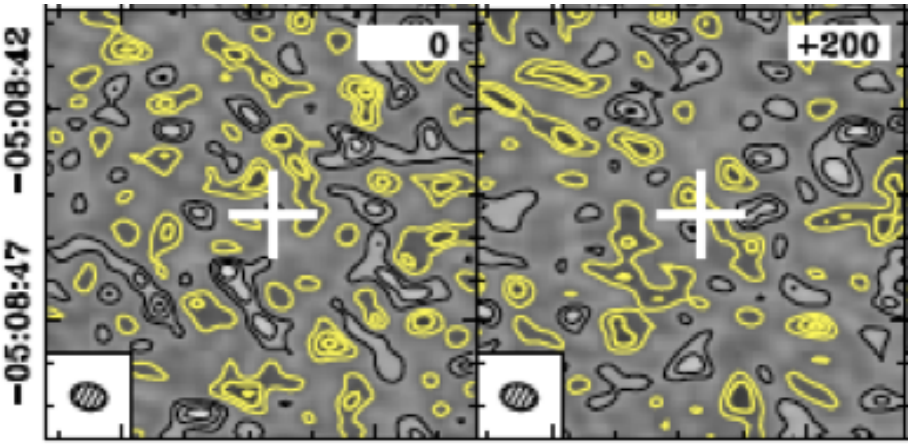
LAE fraction



Submm lines

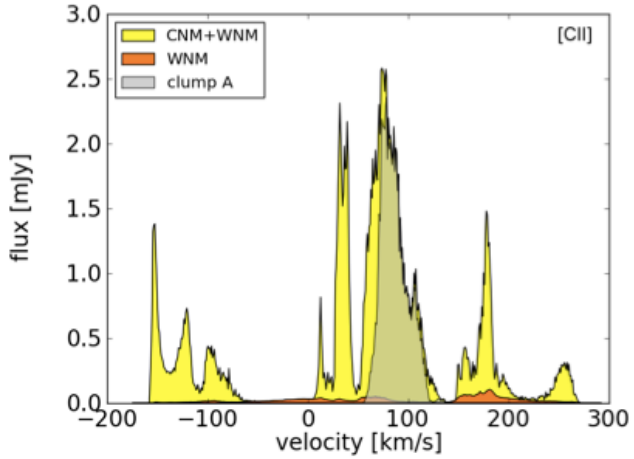

波長
[μm]
1000
100
10
10000
1000
100
10
相対強度
CO (1−0)
CO (2−1)
CO (3−2)
CO (4−3)
CO (6−5)
CO (7−6)
[CI]370
[NII]204
[CII]158
[OI]146
[OIII]88
[OI]63
[NIII]57
[OIII]52
[SiIII]35
[SIII]33
[SIII]19
[NeIII]13
多環芳香族
H2
周波
SMG
LAE-1
QSO
LAE-2
[NII]
[CII]
QSO
SMG
[mJy]
在
z=1.2
85億年前
4億年前

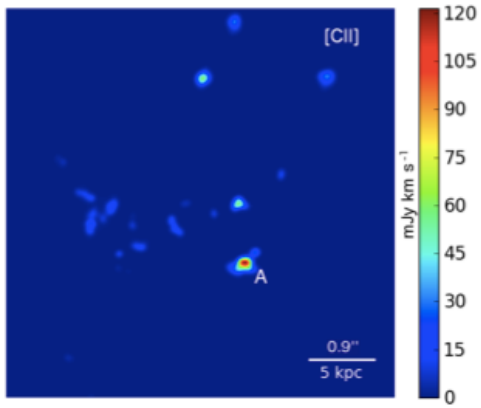
High-z line emitters

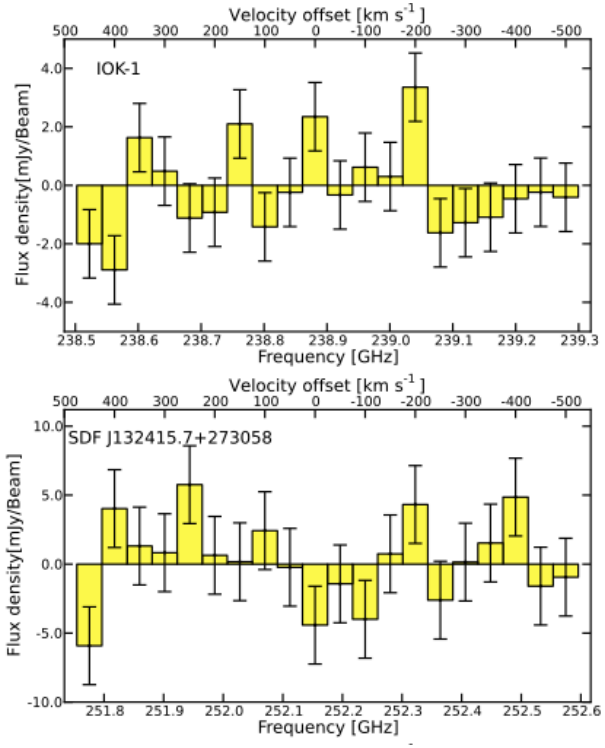


Attempt for 1 object (Ouchi+13)

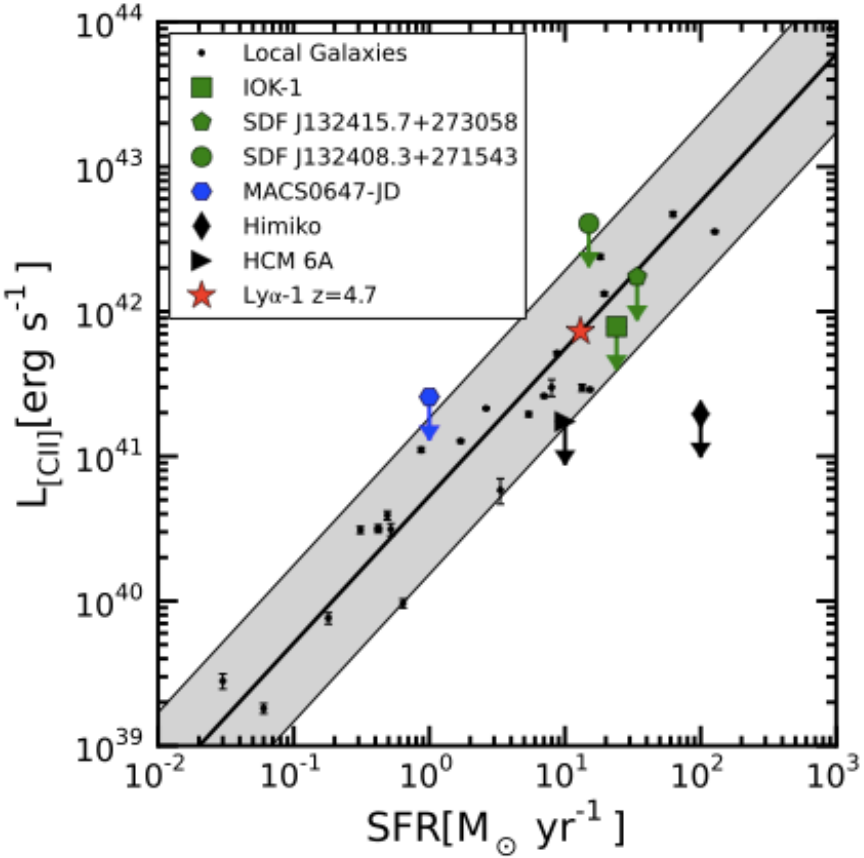
Expectation (Vallini+13)





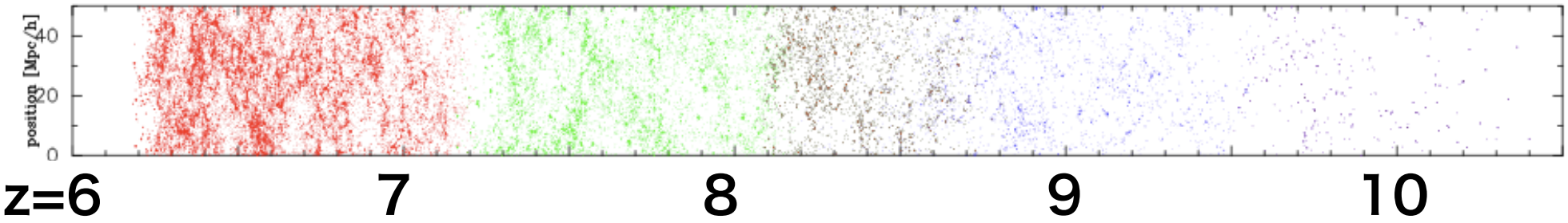


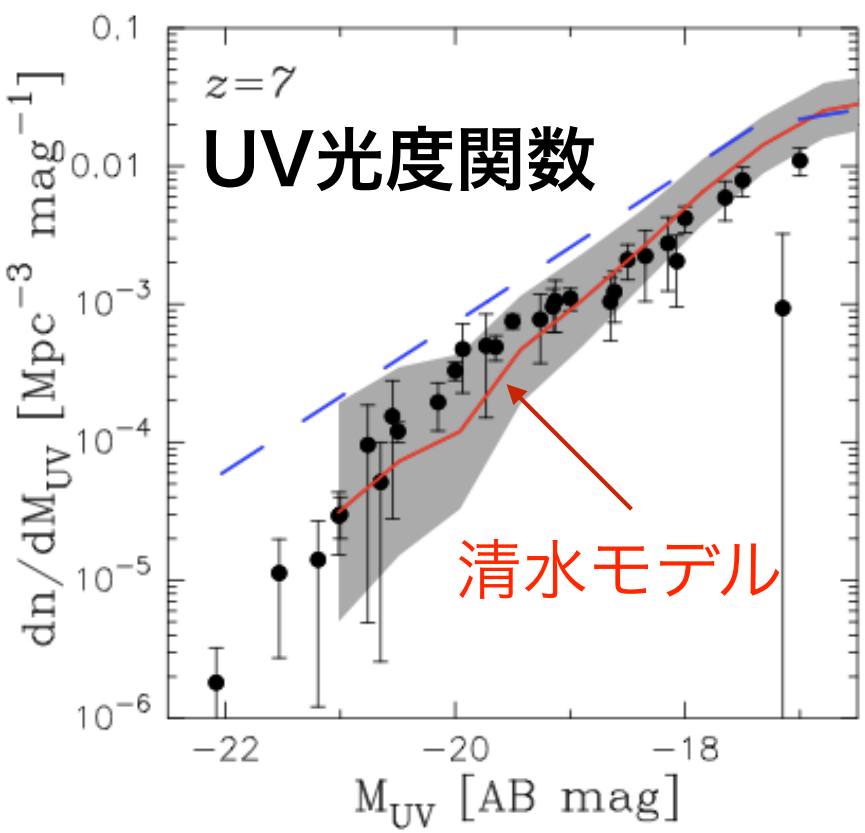
More recent data

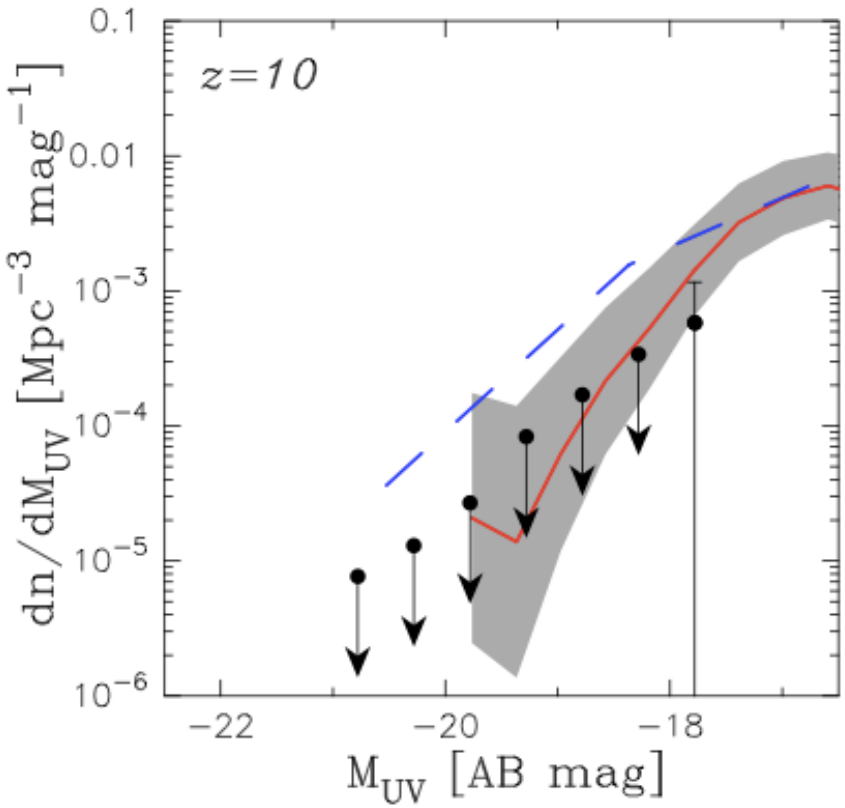


Cosmological simulations

Shimizu et al.

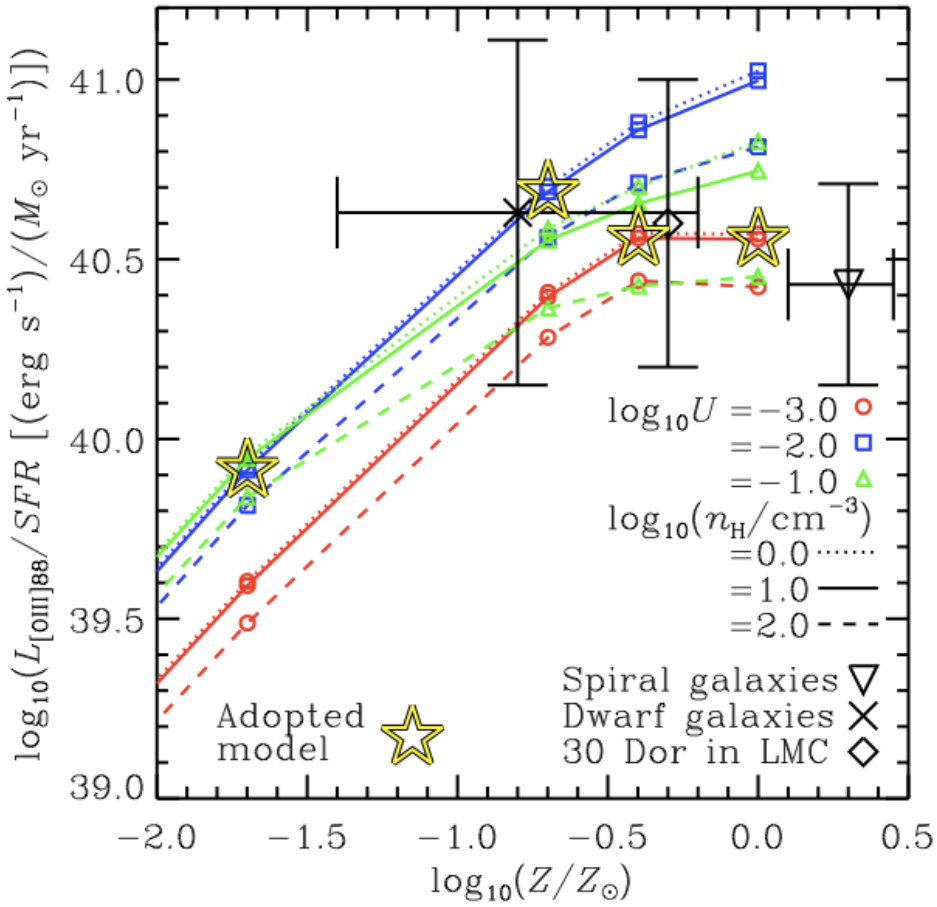


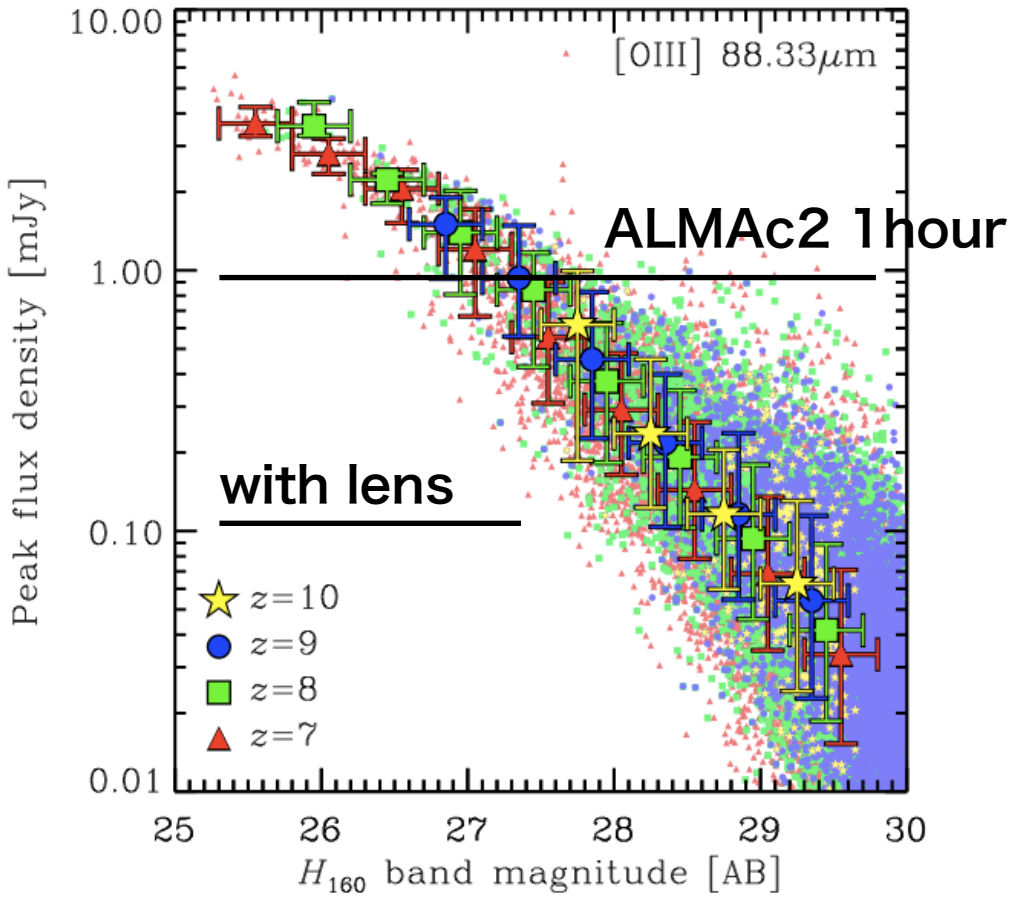




OIII emitters

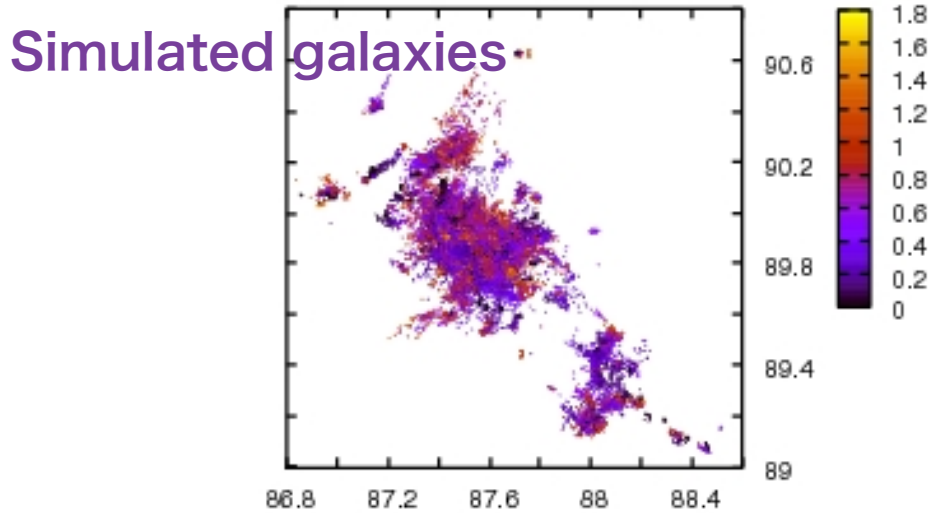
Cosmo. simulation (Inoue, Shimizu et al. 2014, ApJL)

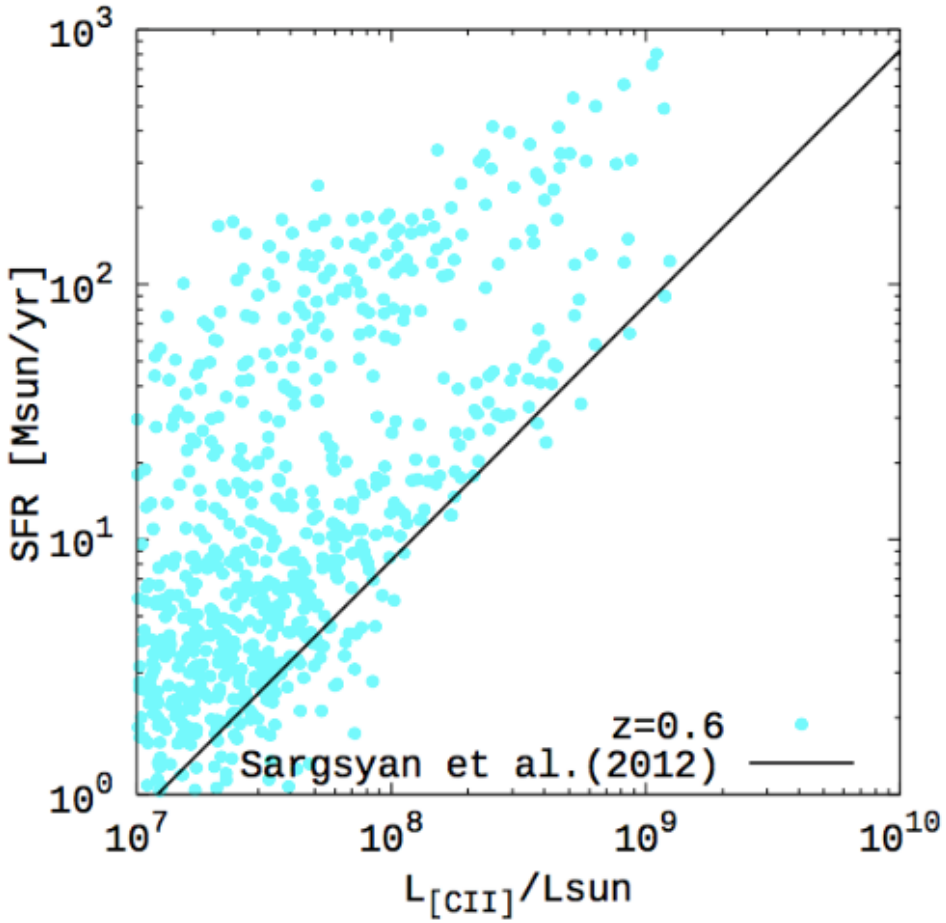


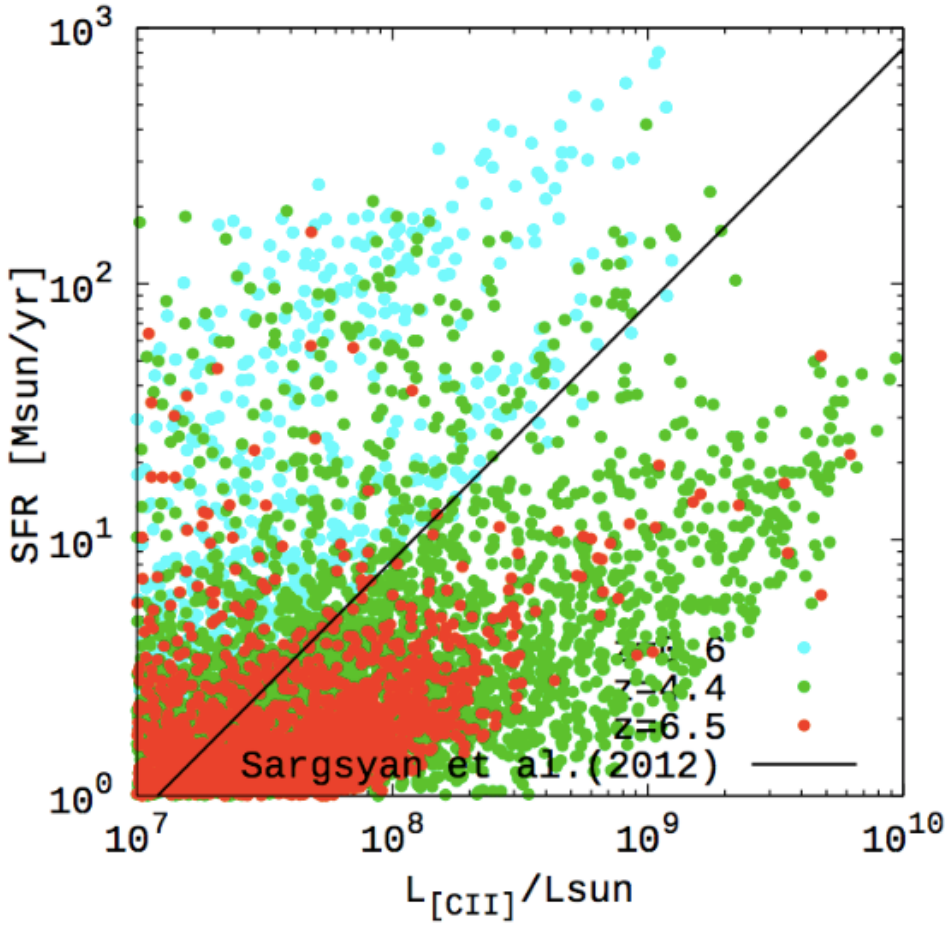


CII emitters

By N. Hayatsu

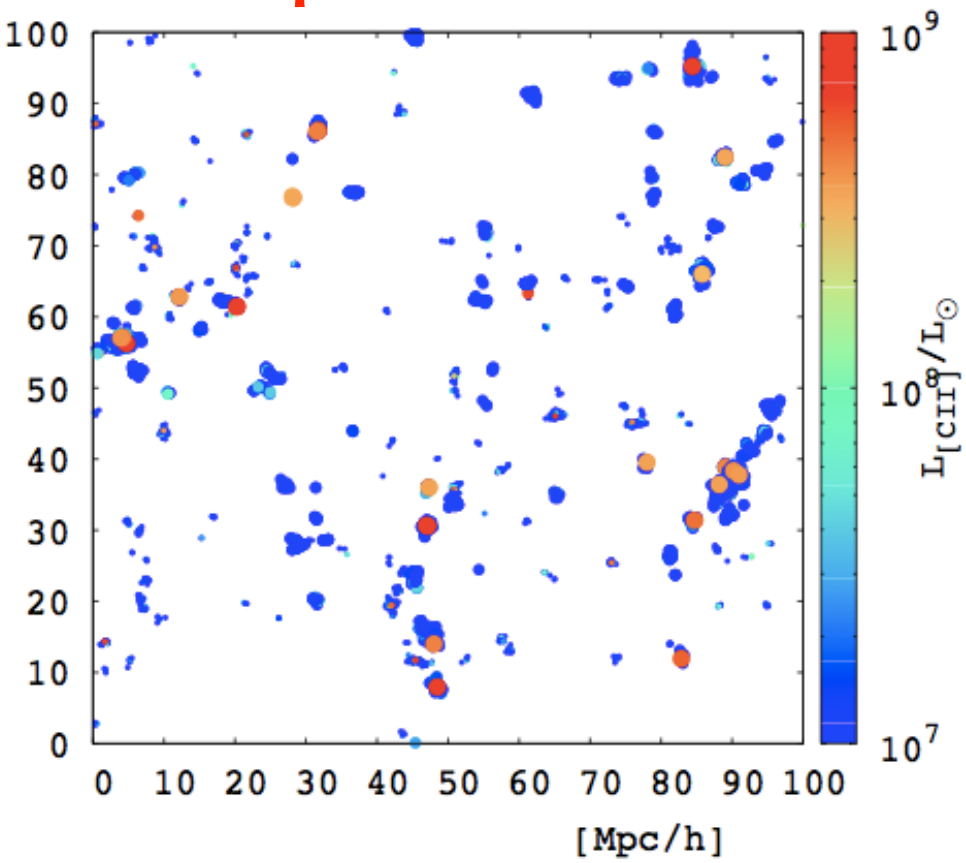


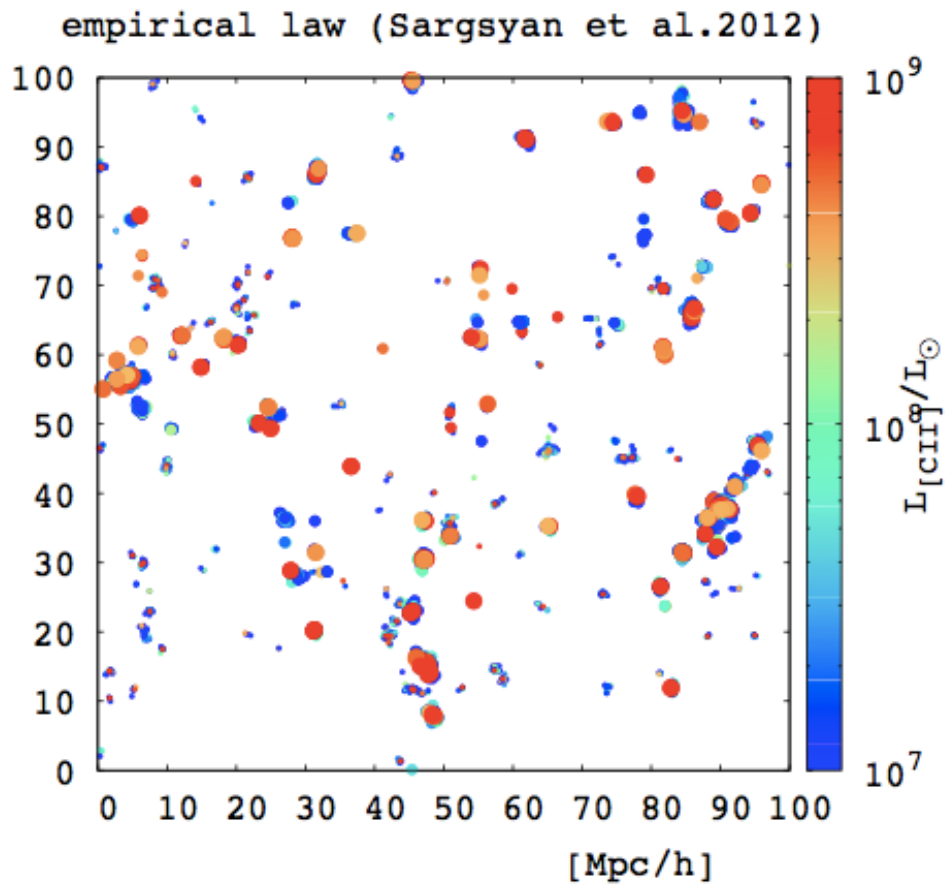




CII emitters

Two-phase model





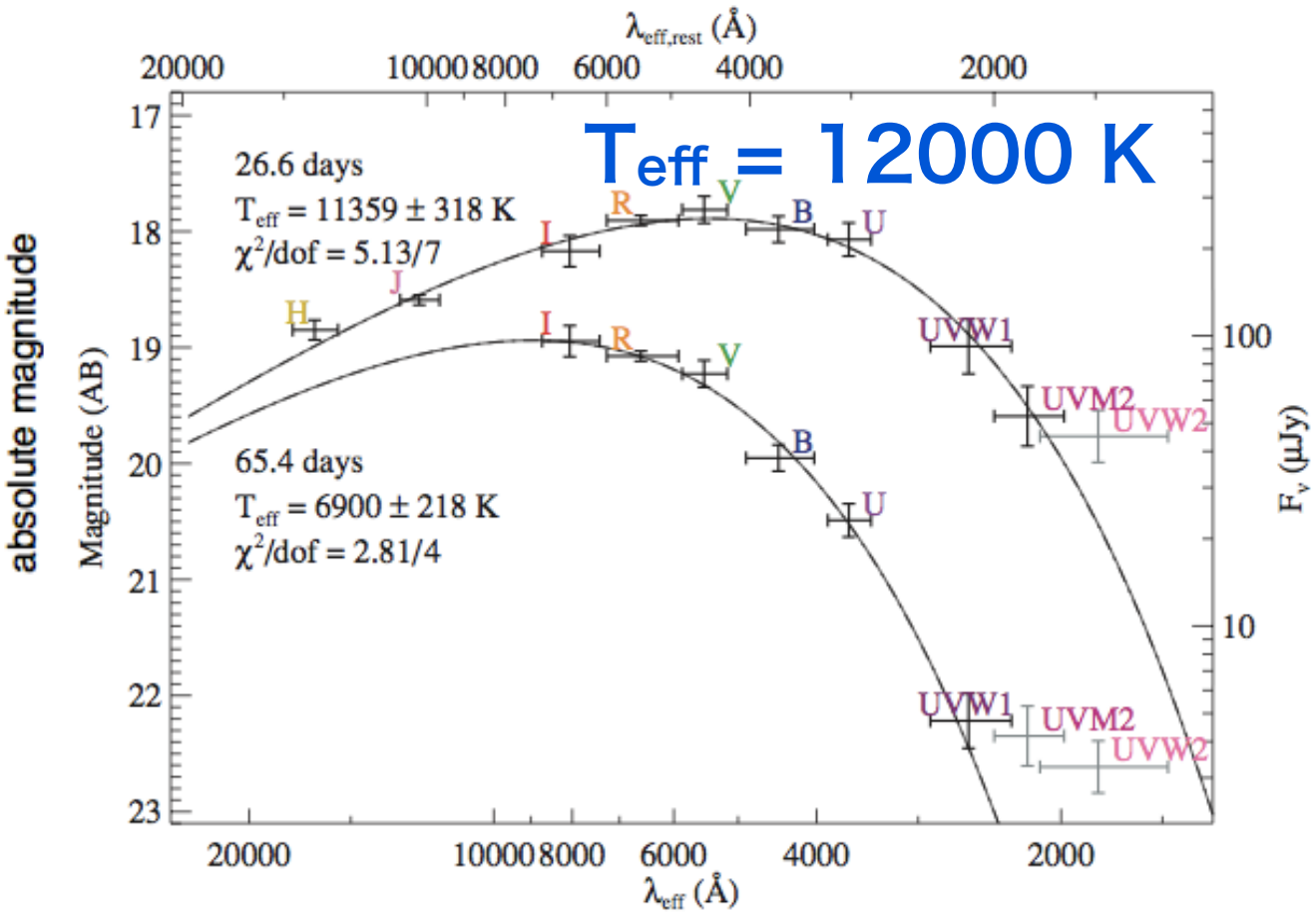
Hunting for Superluminous Supernovae@z>6

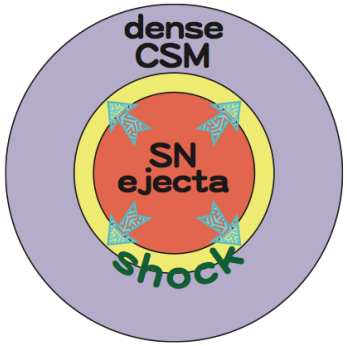
Tanaka, Moriya, NY, Nomoto 2012, MNRAS, 422, 2675

Moriya et al. 2013, MNRAS, 428, 1020

Tanaka, Moriya, NY, 2013, MNRAS

Super-Luminous SN





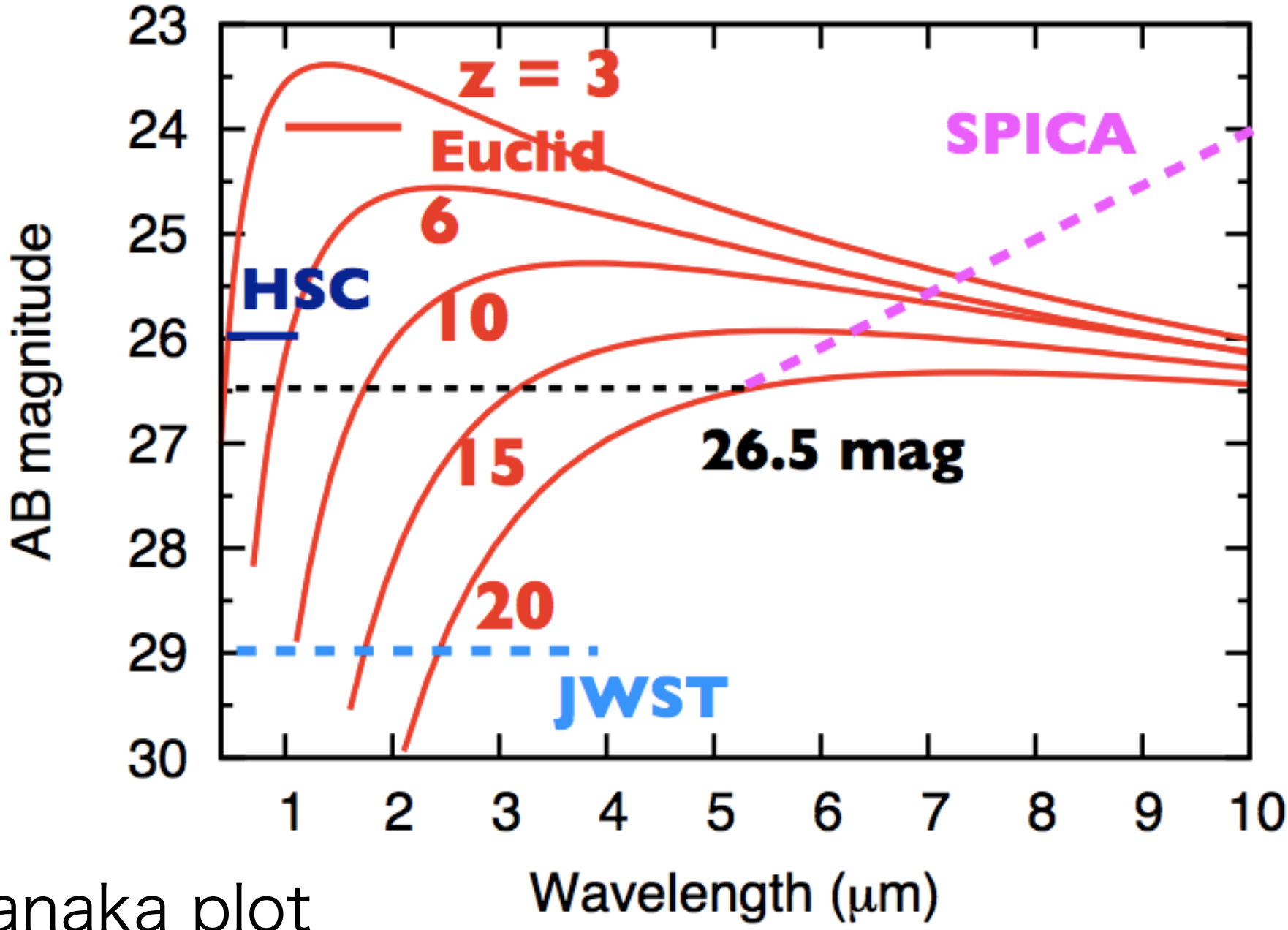
Powered by shock-interaction with dense CSM.

Bright in rest-UV

Death of a very massive star (> 50 Msun?)

They will be visible to very high-z.

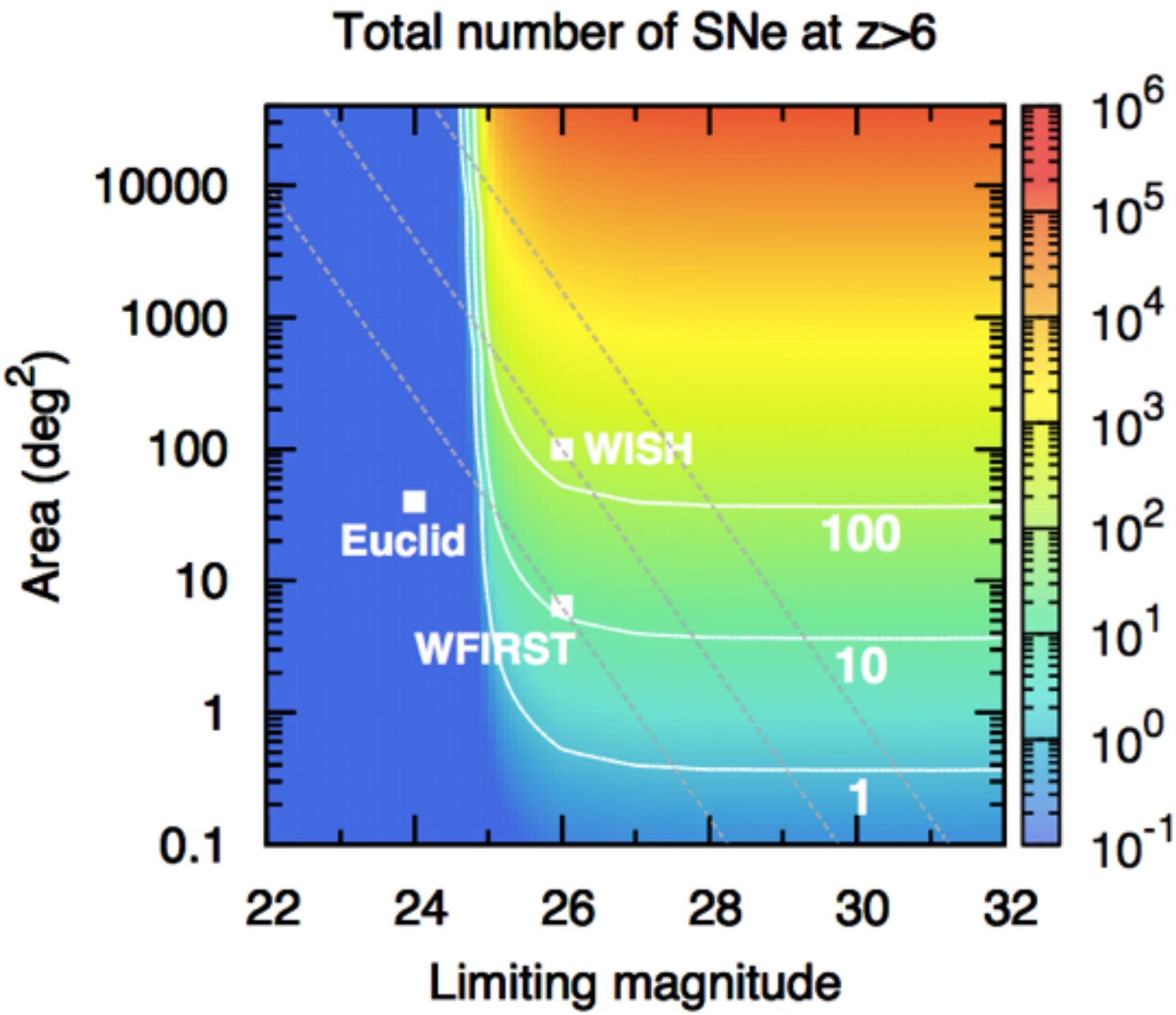
もすこしわかりやすく



Tanaka plot

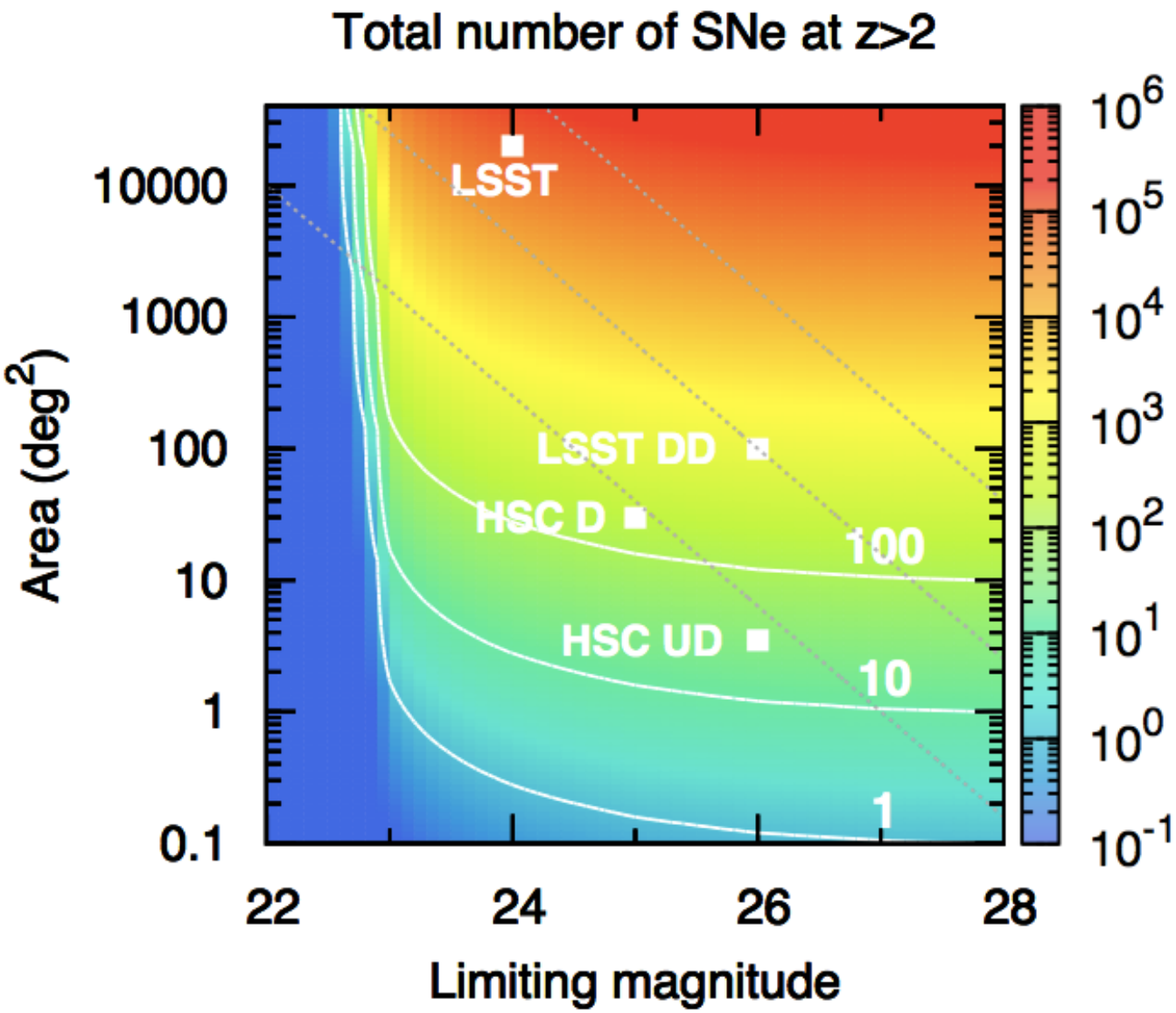
Tanaka, Moriya, & NY, 2013, MN

Beyond z=6: Monte Carlo LC simulation



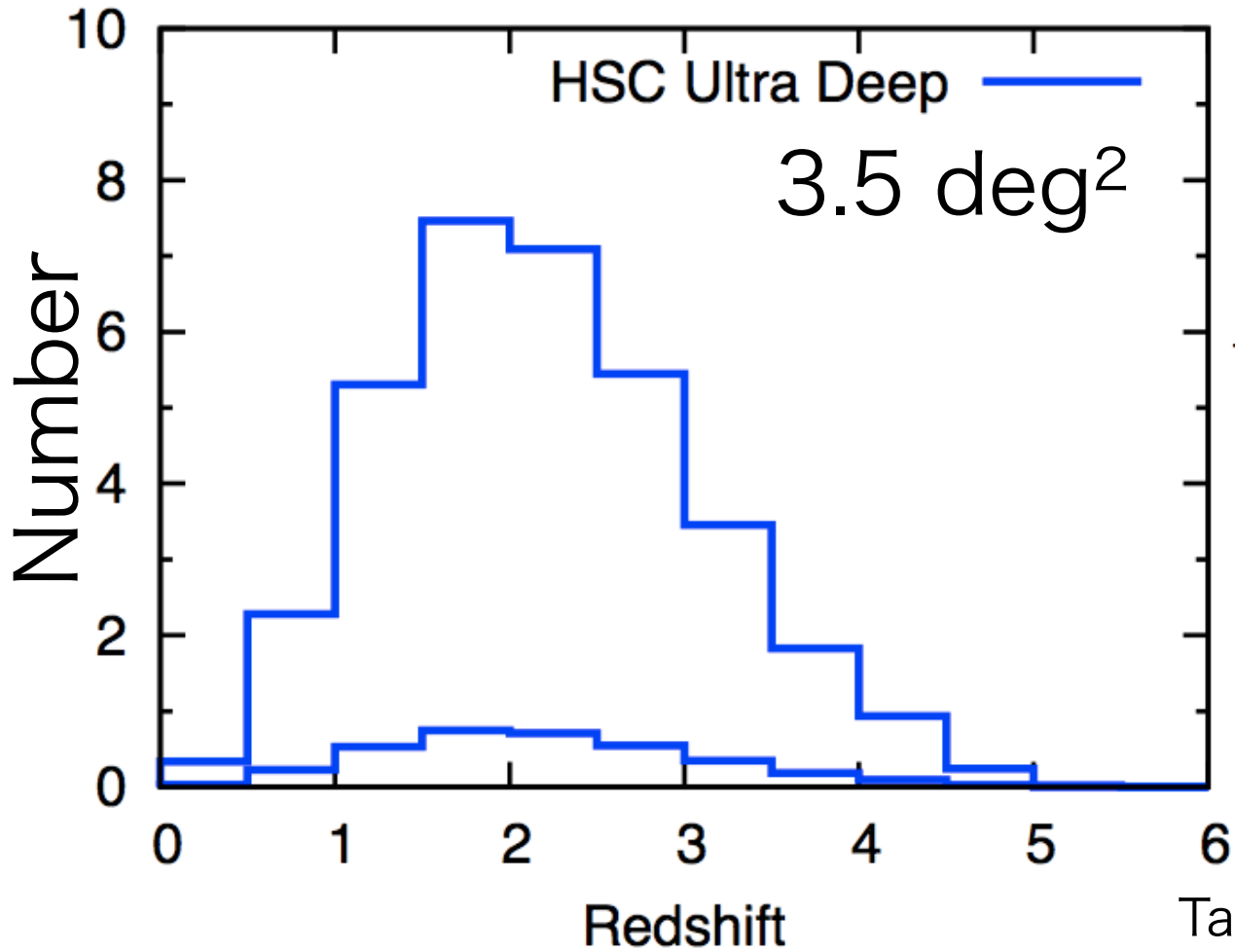
Tanaka, Moriya, & NY, 2013, MN

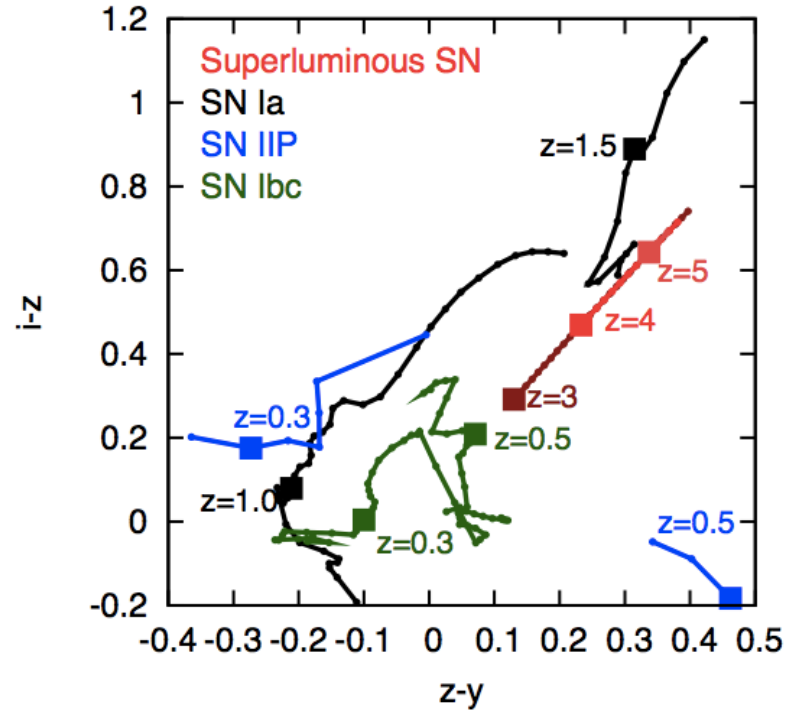
Beyond z=2: Monte Carlo LC simulation



Subaru-HSC 2013-

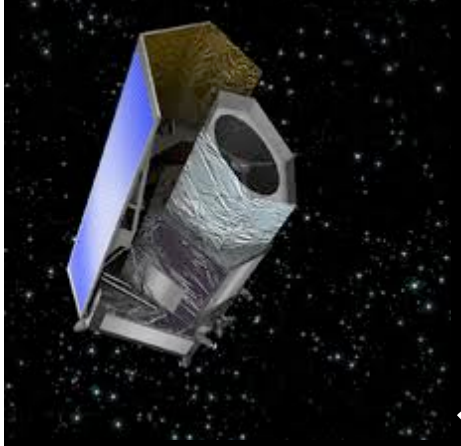
	Area (deg^2)	Δt (day)	n_1	n_2	Limiting magnitude* m_g	m_r	m_i	m_z	m_y
Subaru/HSC Deep	30	6	2	3	26.1	25.8	25.6	24.5	23.2
Subaru/HSC Ultra Deep	3.5	6	3	4	26.9	26.6	26.6	25.6	24.3





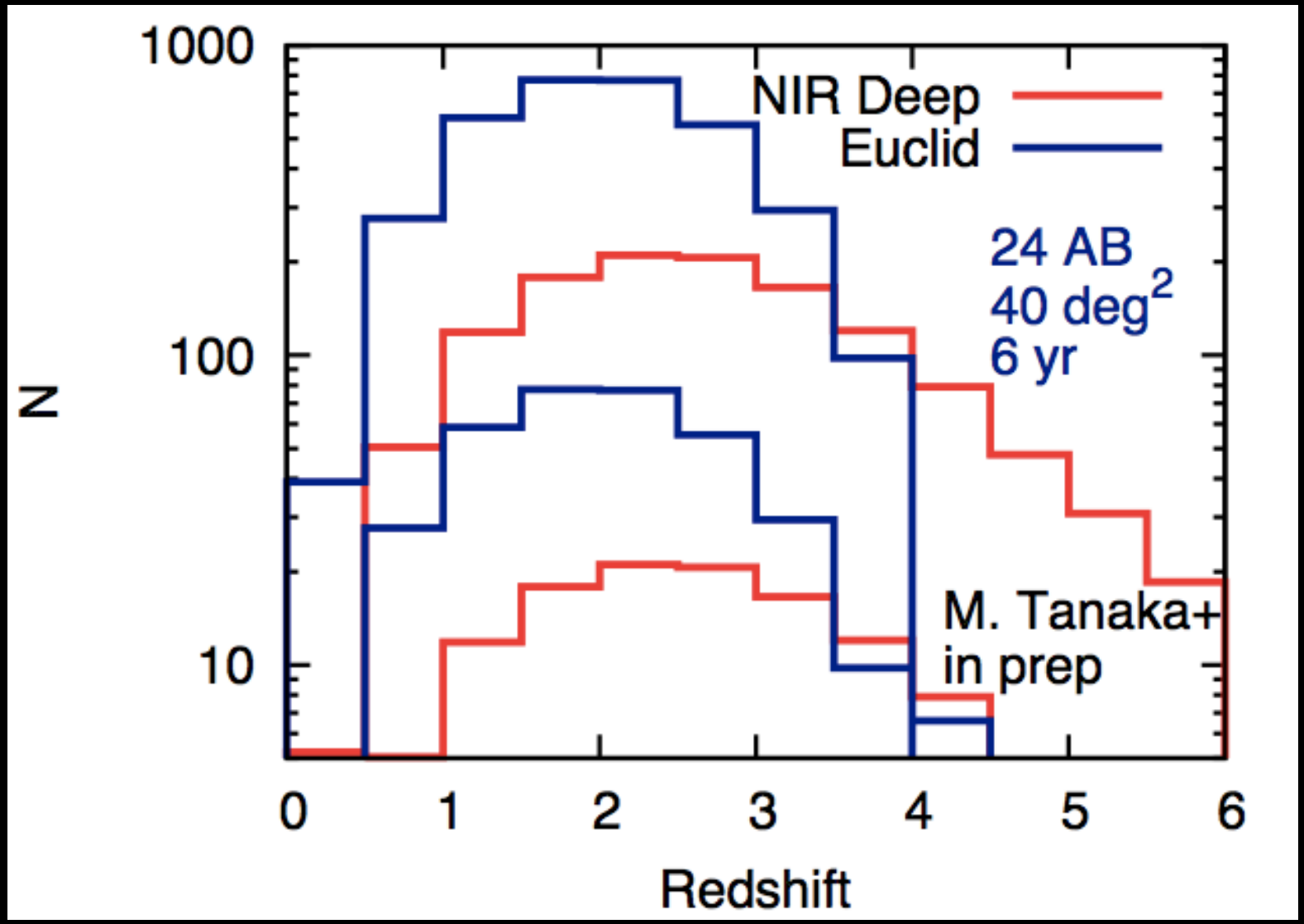
color selection

Tanaka, Moriya, NY, Nomoto, 2012



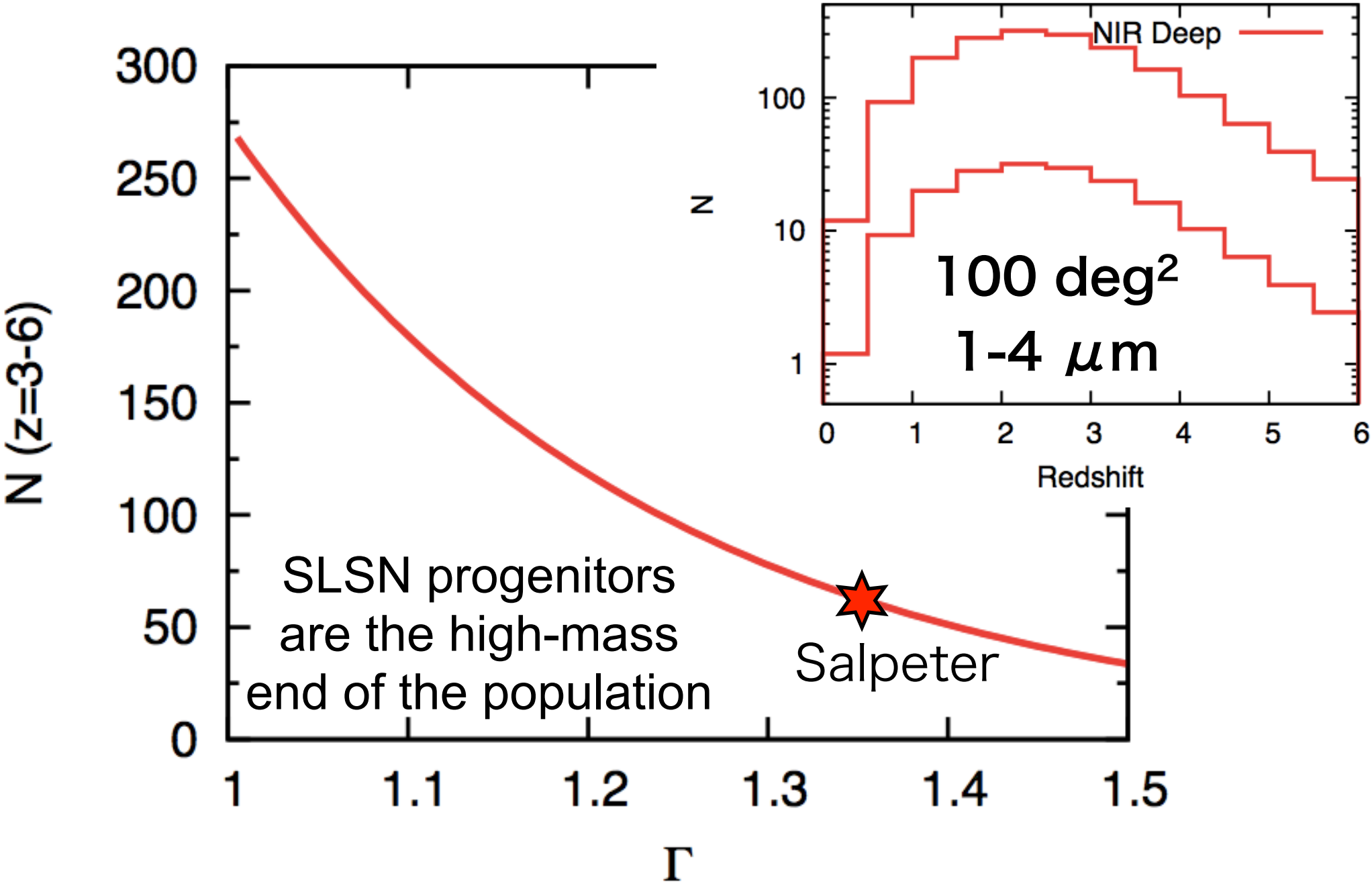
Euclid as SN finder

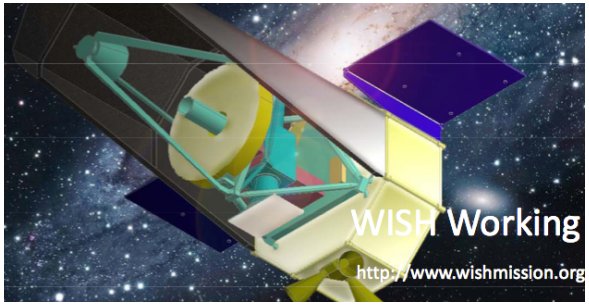
~ 1month cadence over 6 years!



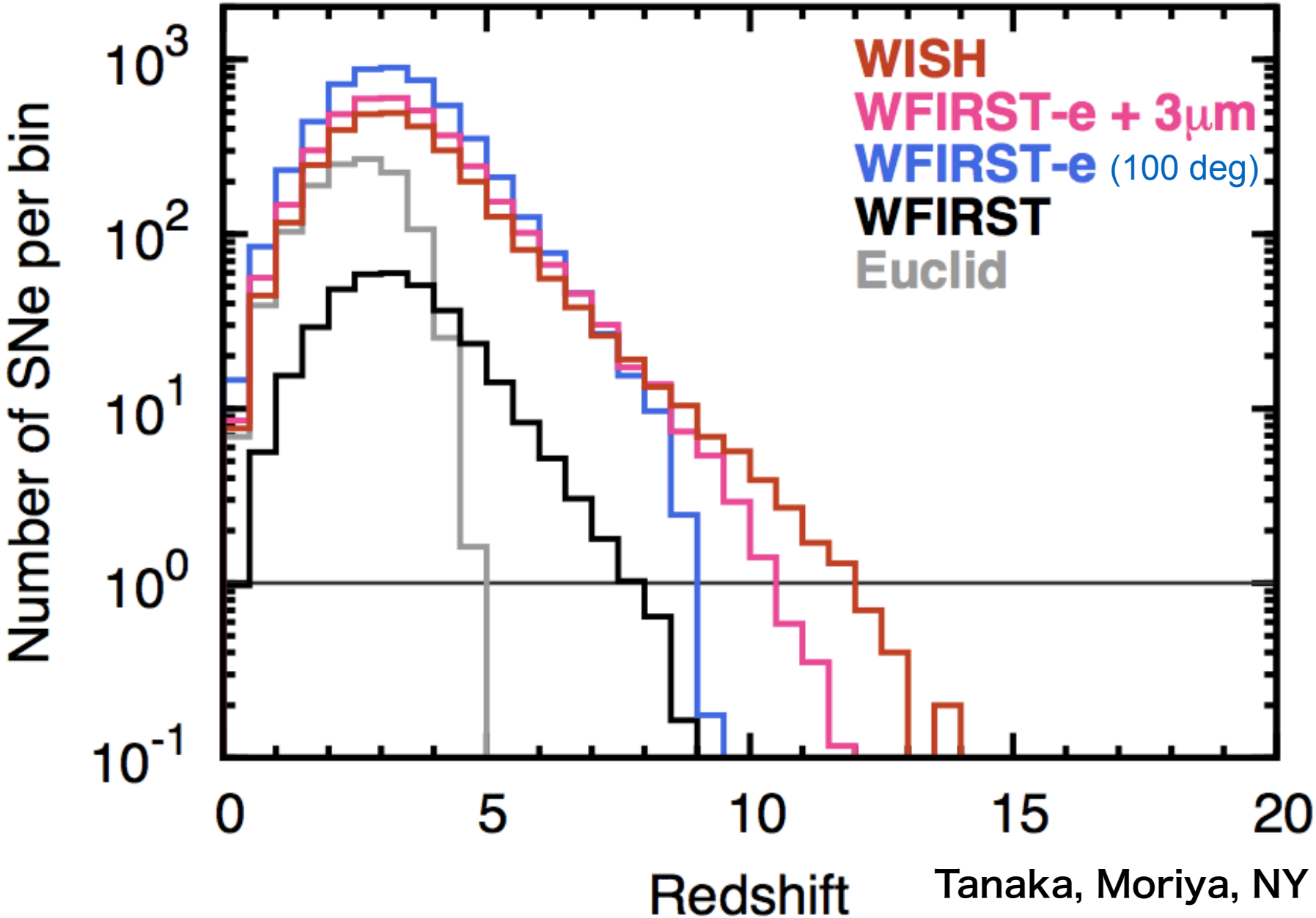
NIR
Y, J, H
bands

Probing stellar IMF

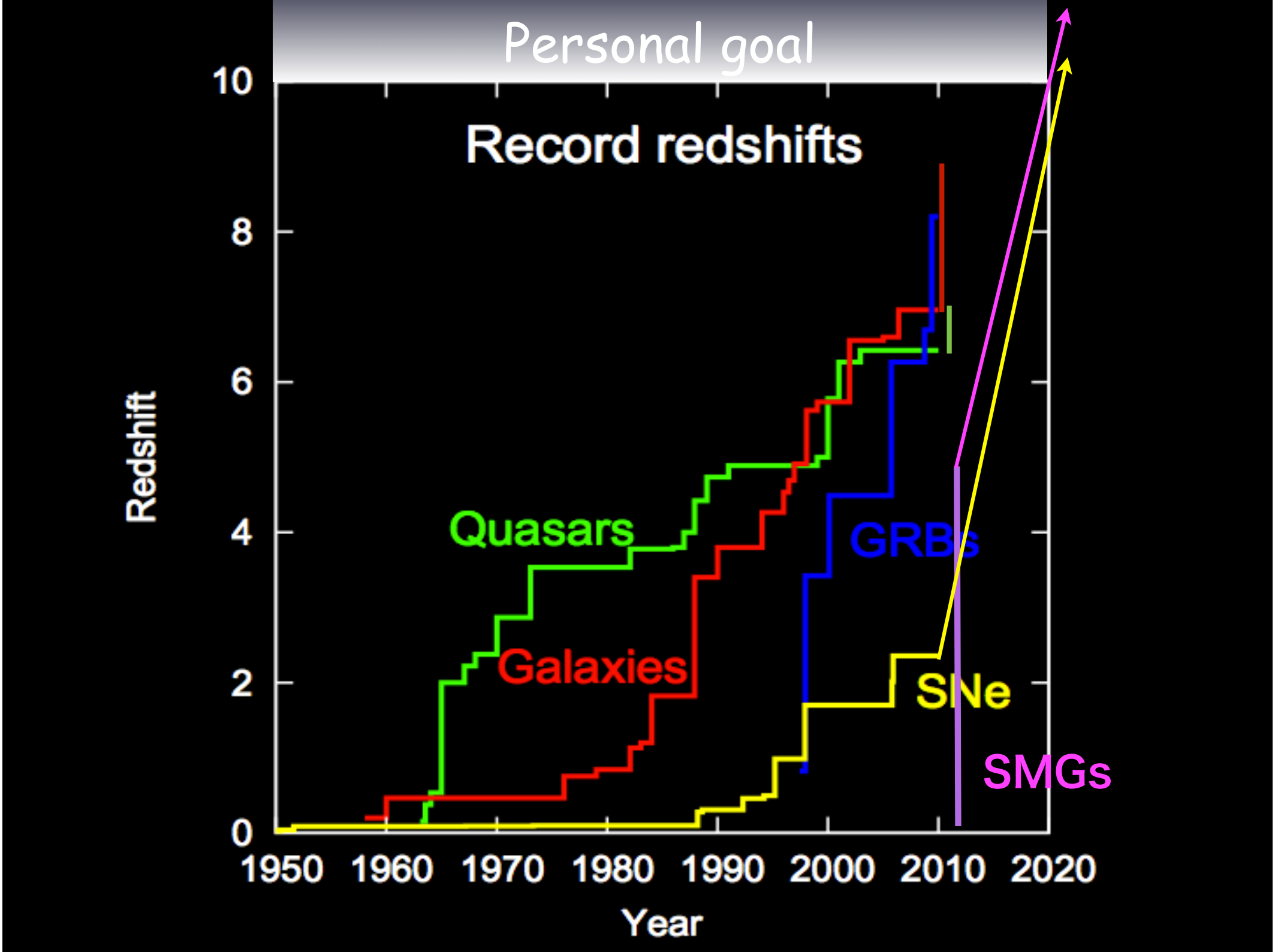




100 deg^2 surveys



Tanaka, Moriya, NY 2013


Personal goal
Record redshifts
Redshift
Year
0
2
4
6
8
10
1950
1960
1970
1980
1990
2000
2010
2020
Quasars
Galaxies
GRBs
SNe
SMGs