Extremely red K – [3.6] galaxies at z ~ 6

（Mawatari et al., submitted to ApJ）

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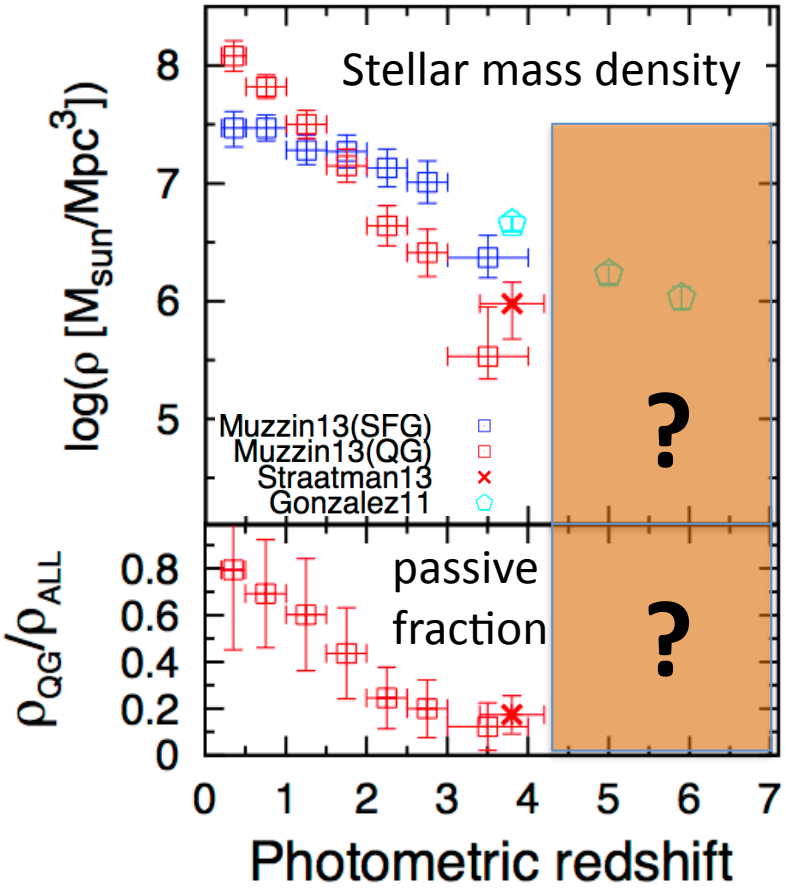
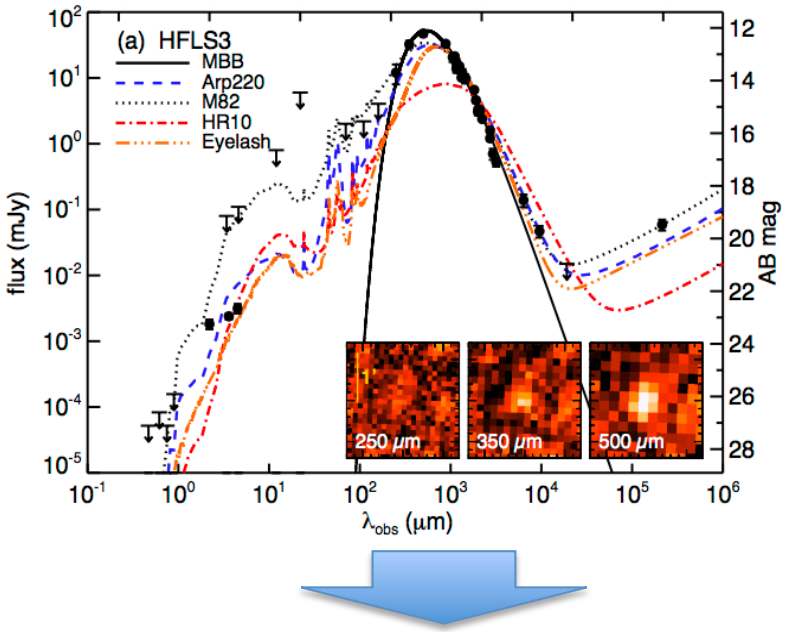
Background

When and how highest-z quiescent galaxies form?



Dust-enshrouded `maximum' starburst galaxy@z～6.34（Riechers+13）
：SFR=2900Msun/yr



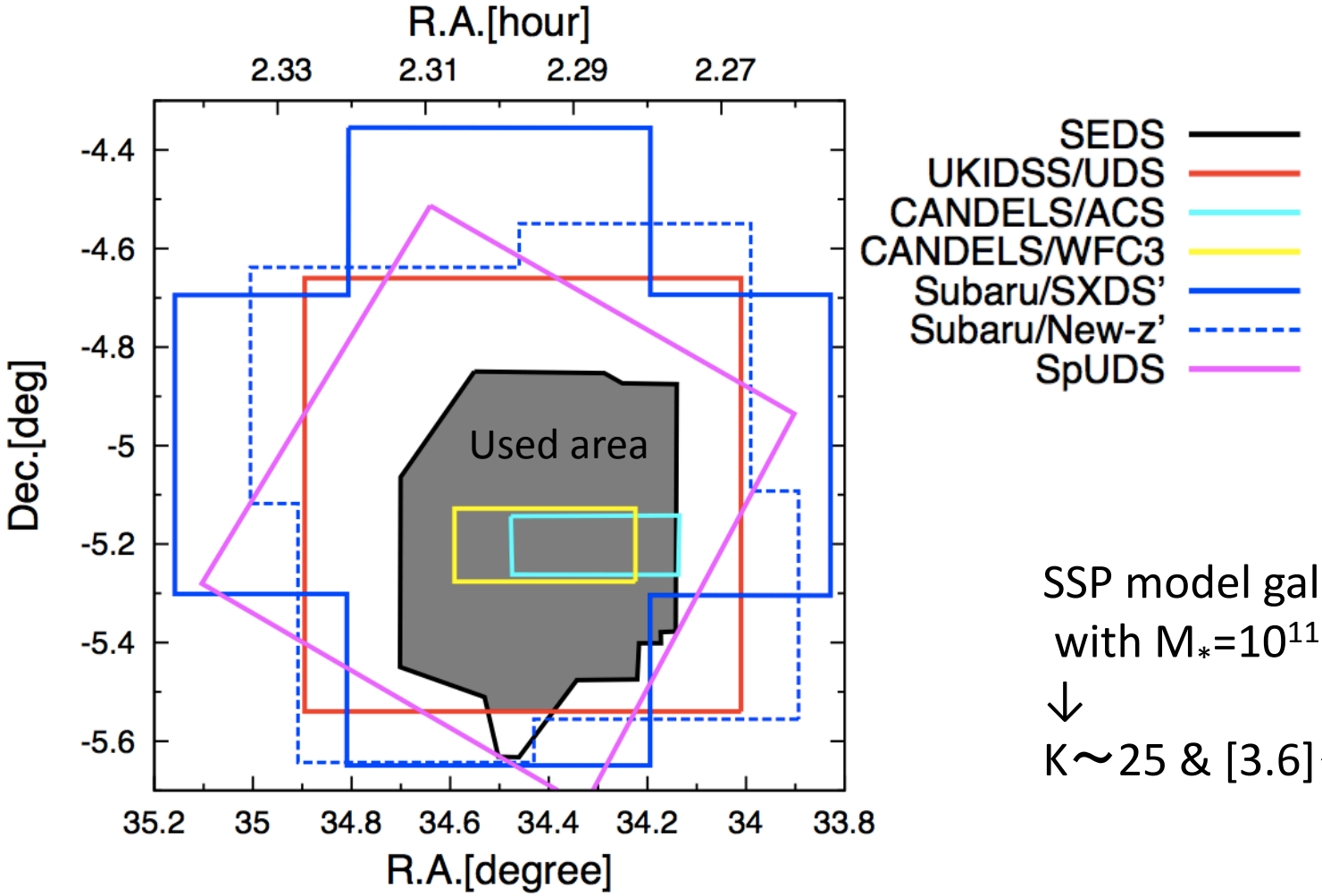
Stop star-formation and experience passive evolution at z > 5?

Motivation

(1) Search for post-starburst galaxies at z > 5（2）composition of red K – [3.6] objects

Analysis: Data

Spitzer Extended Deep Survey(SEDS)/UDS field => Wide-field(0.34deg^2) and deep multiband photometry(5σ～24.5 in K & 25.4 in 3.6um)



SSP model galaxy
with $M_*=10^{11}M_{sun}$@z～6
↓
K～25 & [3.6]～24mag

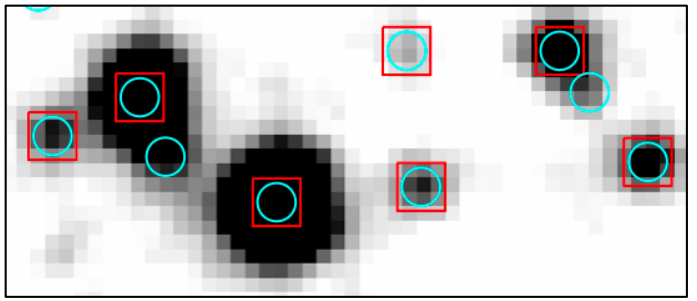
Analysis: Sample selection

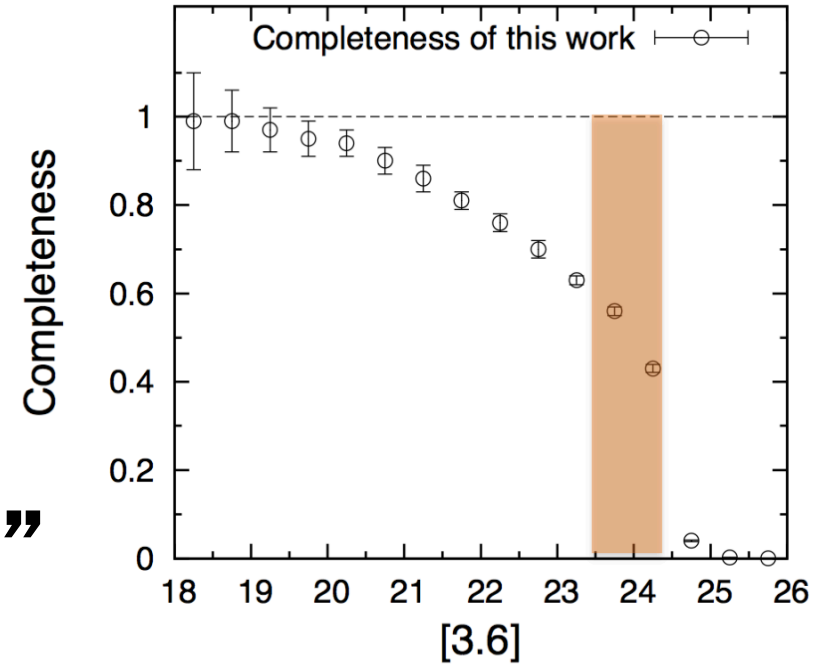
● KIRAC selection

- Object detection on the 3.6um image
  with SExtractor
  focus on relatively isolated objects
  for secure photometry
- aperture photometry (Φ=2.4'') in B～8.0um
  PSF correction : adjust to FWHM=1.9'' (3.6um)
  B～K => image convolution
  5.8um, 8.0um => aperture correction assuming point sources
- Select objects with K − [3.6] > 1.3
  threshold was determined from z～5 SSP model galaxies of Bruzual & Charlot (2003)

⇨ **38 objects** "KIRAC"

Our detection (red) and
SEDS catalog objects (cyan)





Analysis: Sample selection

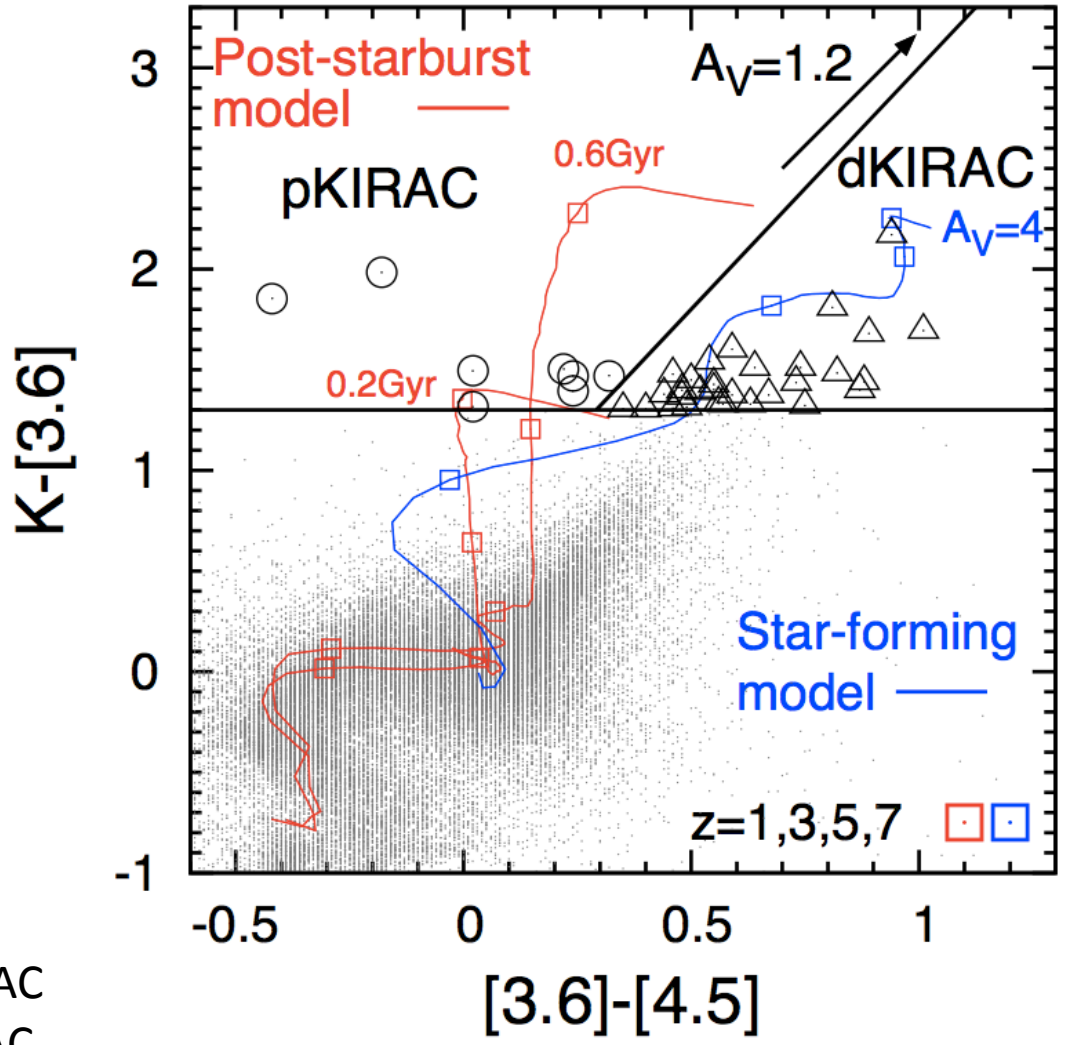
p/dKIRAC classification:

K-[3.6] > 2.4([3.6]-[4.5])+0.6
=> pKIRAC (post-starburst)
K-[3.6] > 2.4([3.6]-[4.5])+0.6
=> dKIRAC (dusty)

8 pKIRACs

30 dKIRACs

※more detailed model expectation
strong nebular line emitters
（Hα@z～4.5 & [OIII]@z～6） => pKIRAC
Av>6 dusty star-forming => pKIRAC
Type-2 AGN => dKIRAC



Complete classification is impossible only with 2 color diagram

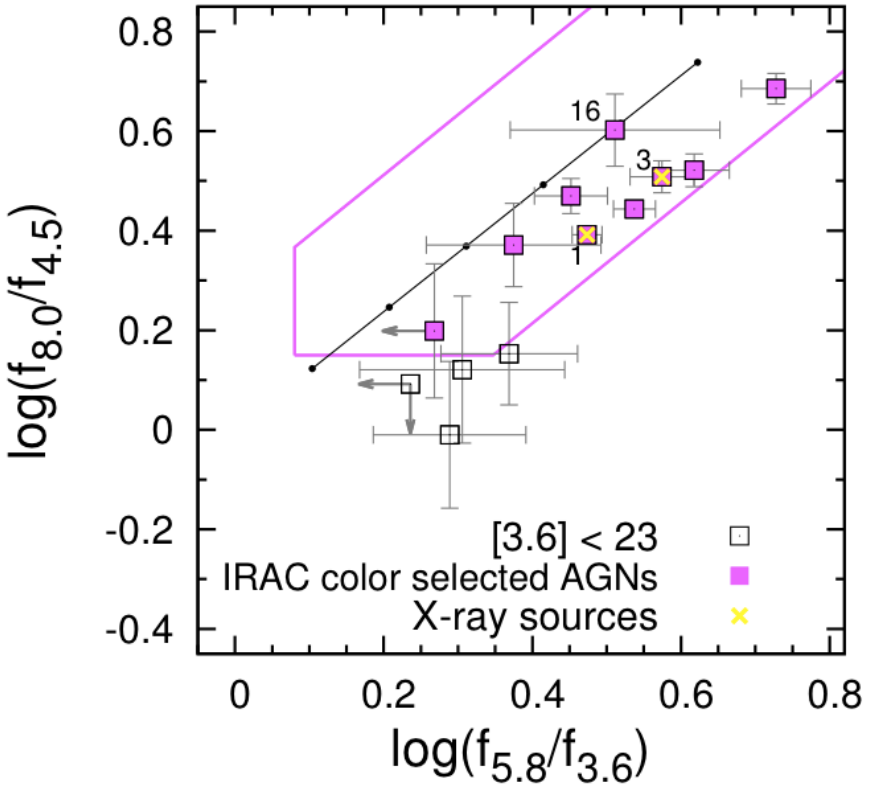
Result: dKIRACs

●Galaxy composition of dKIRACs

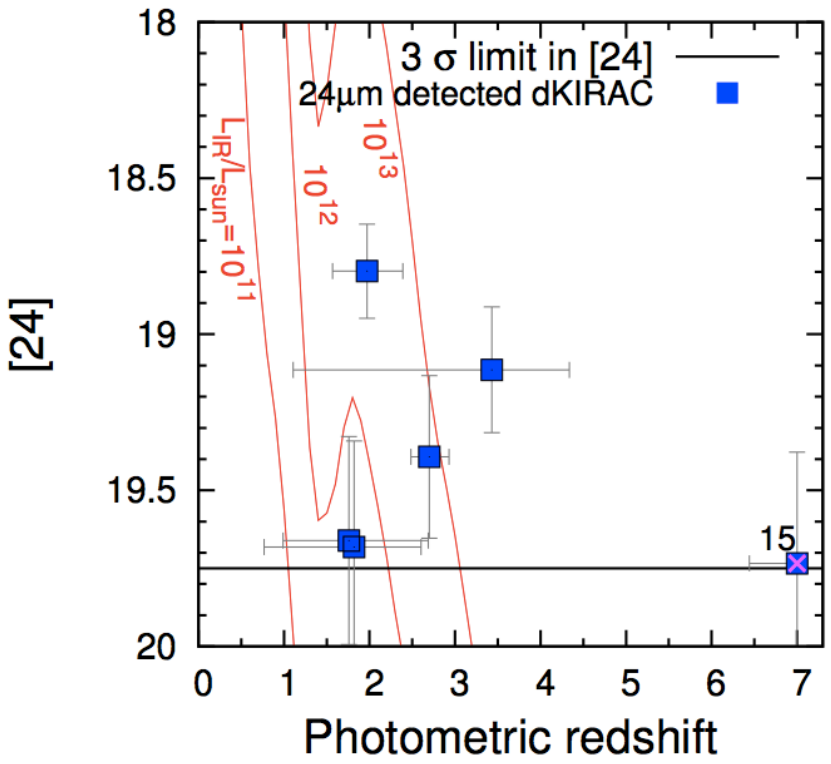
(1) 15 dKIRACs with the 24um detection（[24]<19.75）

=> 10 AGNs(Type-2) + 5 LIRGs

Donley+12 AGN color selection



Comparison with LIRG model of Rieke+09



(2)Another 15 dKIRACs => we cannot yield any constraint

Result: pKIRACs

●Candidate post-starburst galaxies at z > 5

Def. passively evolving after stopping their star-formation

Among the 8 pKIRACs,

2 => Contamination by nearby other objects

3 => Nebular emitters

(i & z detection : strong UV continuum)

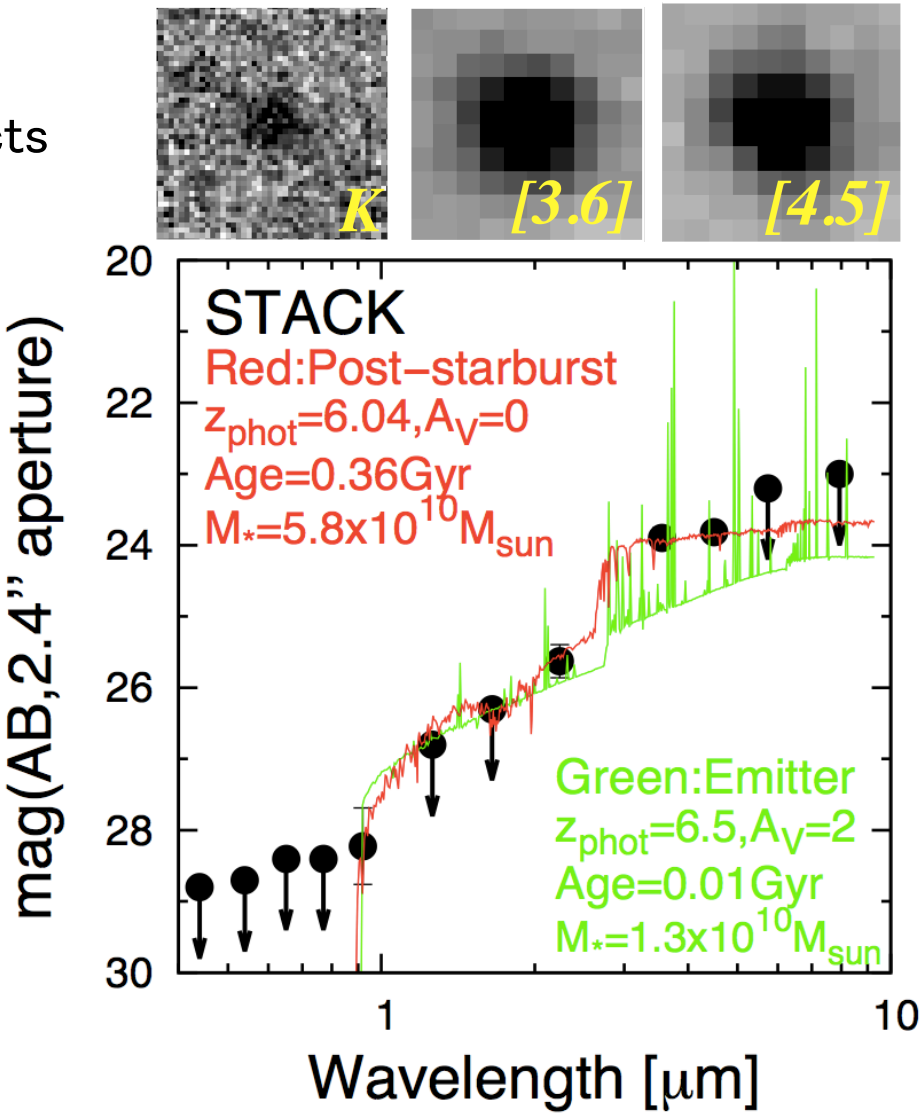
3 => Non-detection in B～z, 24um(2σ)

↓

STACK

SED fitting

- Best-fit by post-starburst template at z =6
- Strong [OIII] emitter at z = 6.5 is also acceptable, however, massive&dusty&high-EW_0(～1000Å) is not realistic



Result: pKIRACs

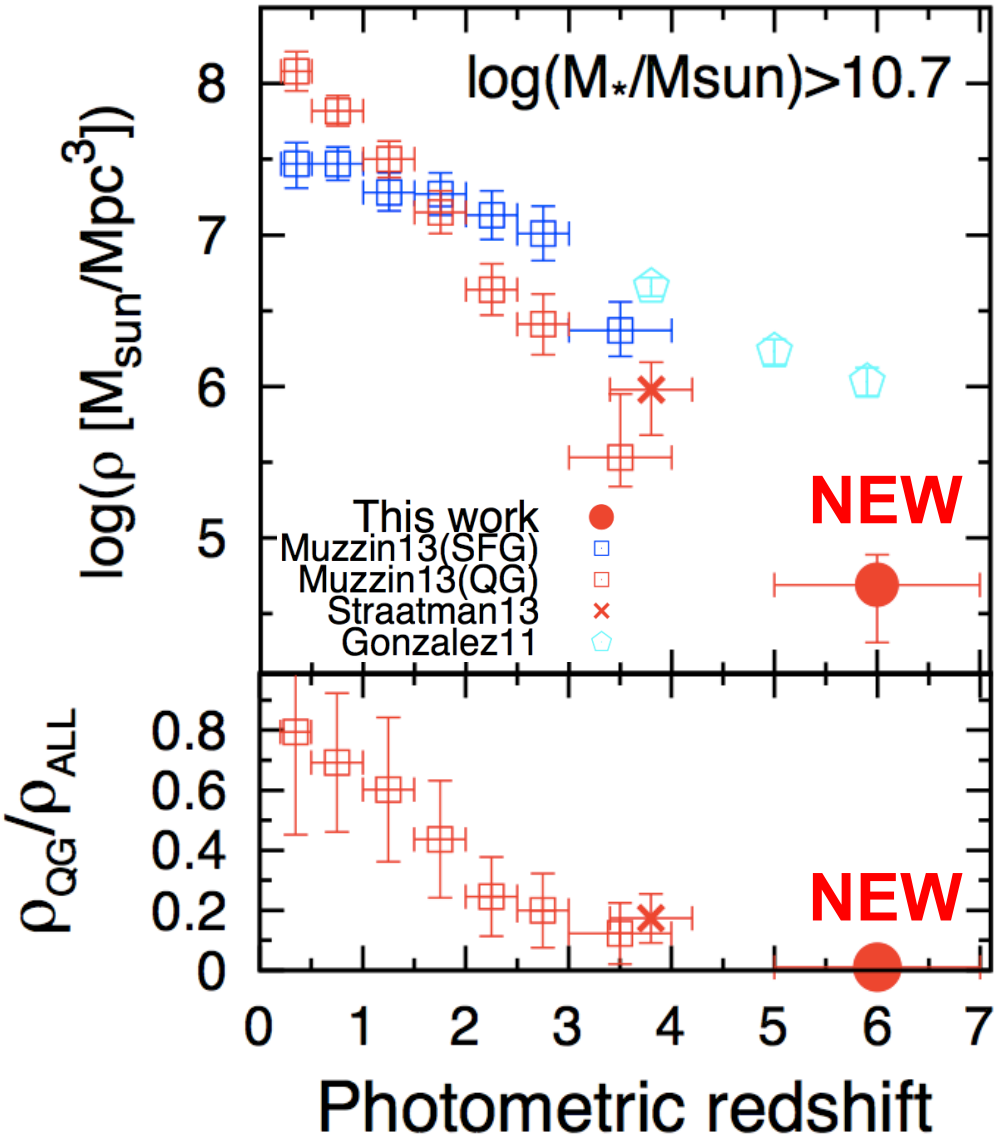
● Stellar mass density evolution of quiescent galaxies up to z = 6

Post-starburst candidates
Number density～8.2 x 10^{-7} Mpc^{-3}
Stellar mass density
～4.8 x 10^4 M_{sum}/Mpc^3

※z=5～7、incompleteness is corrected

- consistent with the trend at z = 0 - 4
- passive fraction～1%

Formation and quenching of first massive galaxies in the universe was proceeded by z = 5 !



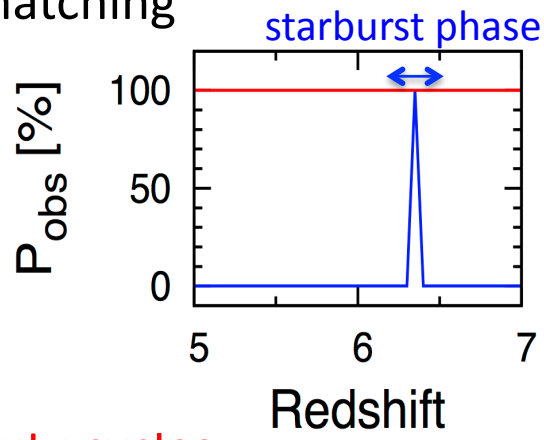
Discussion

●dusty starburst => post-starburst @z>5？

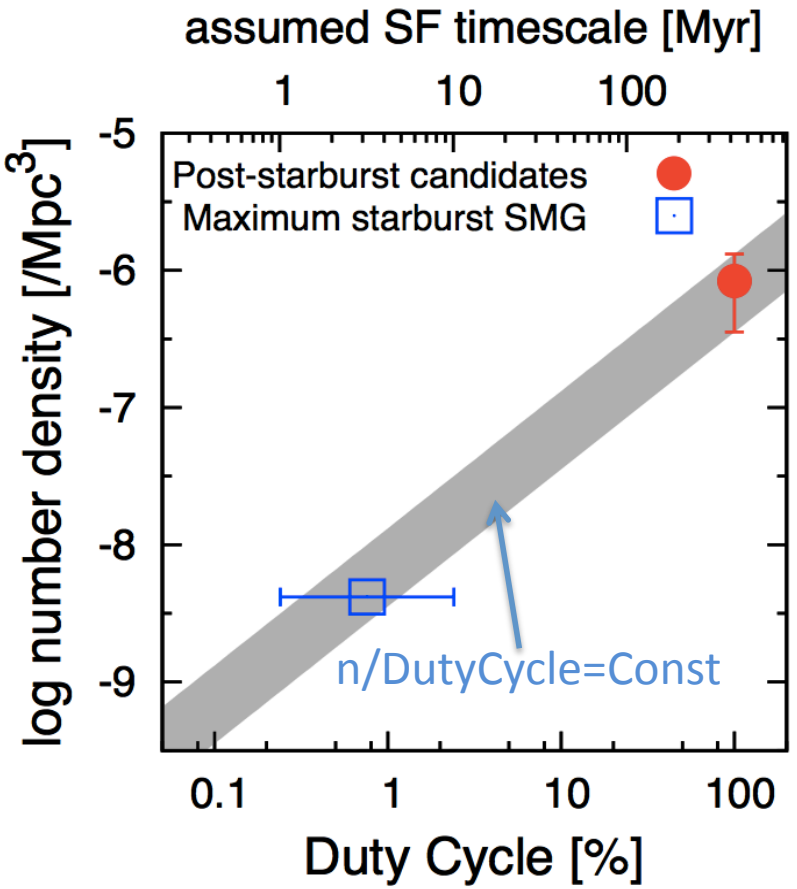
・`Maximum' star-burst galaxy@z=6.34 (HFLS3; Riechers+13).
: M_*=3.7x10^{10}, M_{gas}=10^{11}, SFR=2900Msun/yr
↓
At z～5, this should become the post-starburst galaxy with similar age and stellar mass as our candidates.

・Simplified abundance matching

※star-formation timescale= 1 - 10Myr
（⇔ Duty Cycle=0.2-2%）



Taking into account of duty cycles, abundance of our candidate post-starburst galaxies is consistent with z>6 `maximum' starburst galaxy



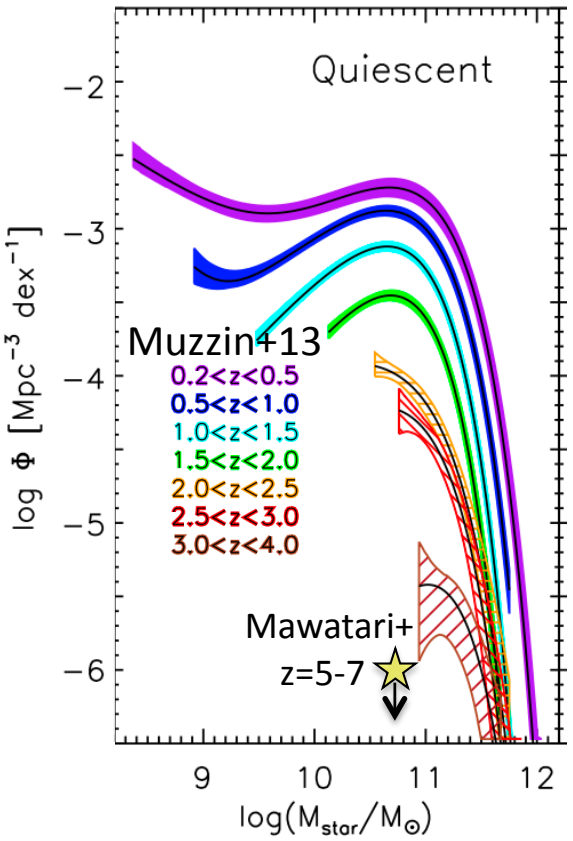
Discussion

●Prediction for WISH UDS

(1) Selection

Current: K-[3.6]>1.3 => z = 5 - 7

WISH : F3-F4>0.8 => z = 5 – 6.5



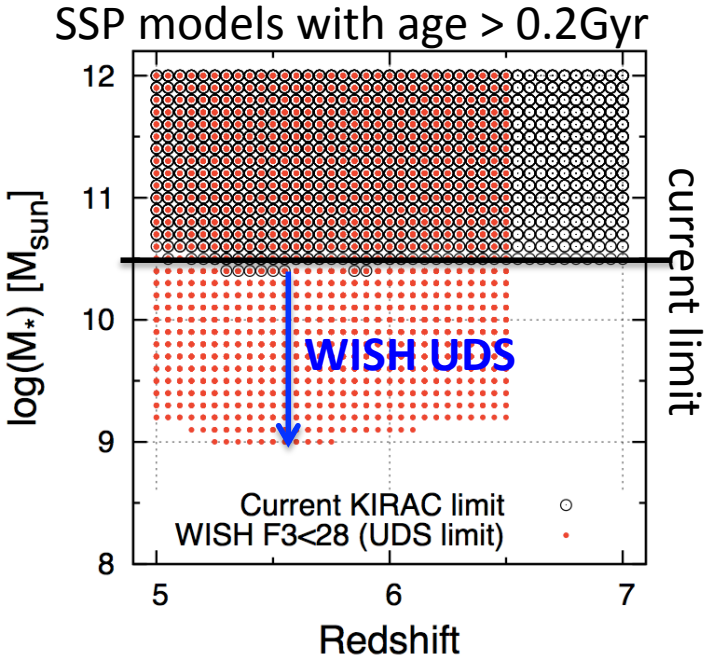
(2) Sensitivity

Current limit (K<25)

=> $M_* > 10^{10.5}\ M_{sun}$

WISH UDS (F3<28)

=> $M_* > 10^{9}\ M_{sun}$



(3) Expected number with UDS

Massive end ($M_* > 10^{10.5}\ M_{sun}$)

: Mawatari+ => 1200 / 100deg^2

Low-mass ($M_* = 10^{9} – 10^{10.5}\ M_{sun}$)

: New window for WISH

Summary

➢ ***Propose "KIRAC" galaxies*** (extremely red K – [3.6] galaxies)

- KIRACs with red [3.6] – [4.5] (dKIRAC) => AGNs and LIRGs
- KIRACs with blue [3.6] – [4.5] (pKIRAC) => may include post-starburst galaxies at z > 5, hidden so far from observations

➢ ***Identification of most likely post-starburst galaxies at z > 5***

- From the pKIRACs, 3 objects are identified as most likely post-starburst galaxies at z > 5
- Fitting for the stacked SED => Post-starburst galaxies at z～6 with 0.36Gyr after stopping star-formation

➢ ***Implication***

- Formation and quenching of first massive galaxies proceeded by z = 5
- Dust-enshrouded starburst galaxies are likely progenitors of our post-starburst galaxy candidates

WISH can detect >1000 KIRAC galaxies down to $M_*=10^9 M_{sun}$!!!