

Discovery of strong Lyman continuum emitting galaxies: Cosmic "ionizer"?

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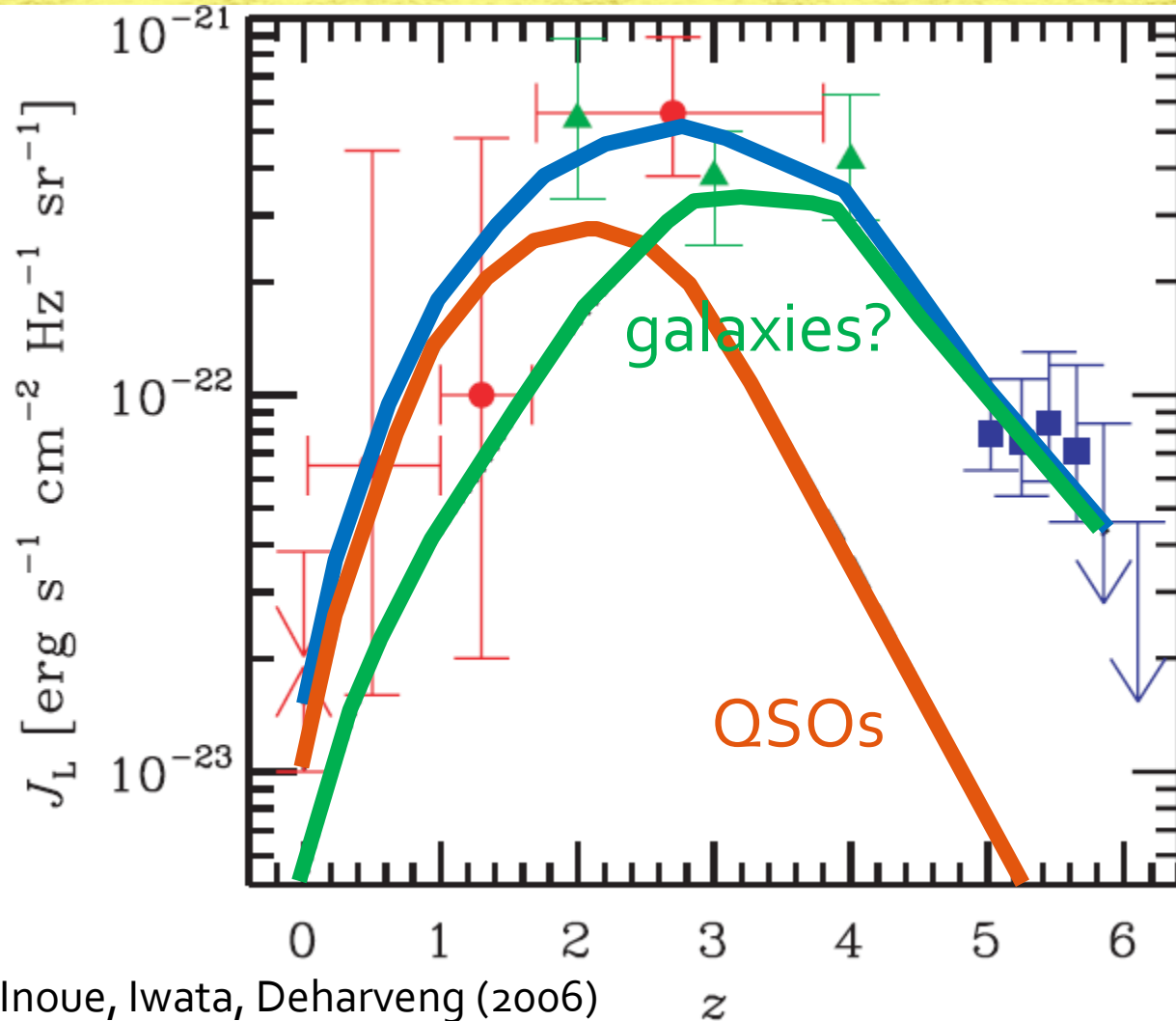
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Abstract

- Young star-forming galaxies should be a main source of ionizing radiation which caused the cosmic reionization. Nevertheless, our knowledge of the galactic Lyman continuum emissivity is still quite poor. Direct detections of the Lyman continuum are challenging but have particular importance. We made Subaru/Suprime-Cam deep narrow-band imaging to search the Lyman continuum from $z \sim 3$ LBGs and LAEs and found that $\sim 10\%$ of the observed galaxies emit a strong Lyman continuum which cannot be explained with a standard population synthesis model with a normal IMF. This new population of galaxies could play an important role on the ionizing background and the cosmic reionization.

Ionizing background: Galaxies? QSOs?

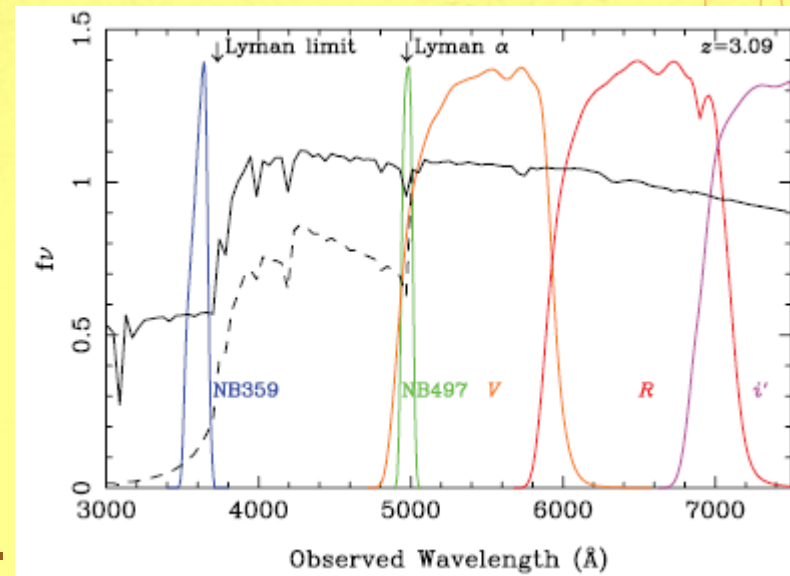


- Optically selected bright QSOs did not contribute at all.
- Galaxies could?
 - So-called Pop-III stars?
 - Undiscovered faint AGNs?

Inoue, Iwata, Deharveng (2006)

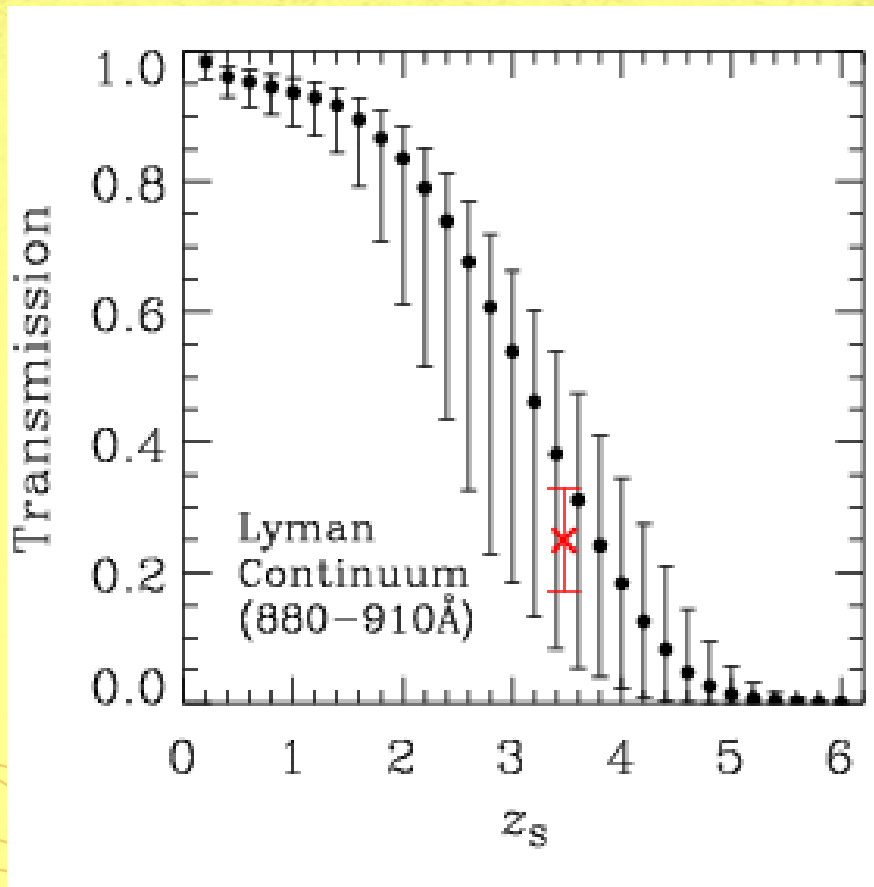
Subaru narrowband survey of LyC

- Field: SSA22 proto-cluster at $z=3.09$
 - ~800 LAEs selected NB497: **125 with spec-z**
 - many LBGs: **73 with spec-z**
- Instrument: Suprime-cam
 - Filter: custom-made **NB359**
 - FoV: 32'x26'
- Observations:
 - On-source exposure: 22.5h.
 - 3-sigma limiting: 27.33 AB (1."2 ap.)



$z \sim 3$: highest- z window for LyC obs.

- IGM opacity rapidly increases higher- z .



Inoue & Iwata (2008):
Monte-Carlo simulation
of IGM transmission.

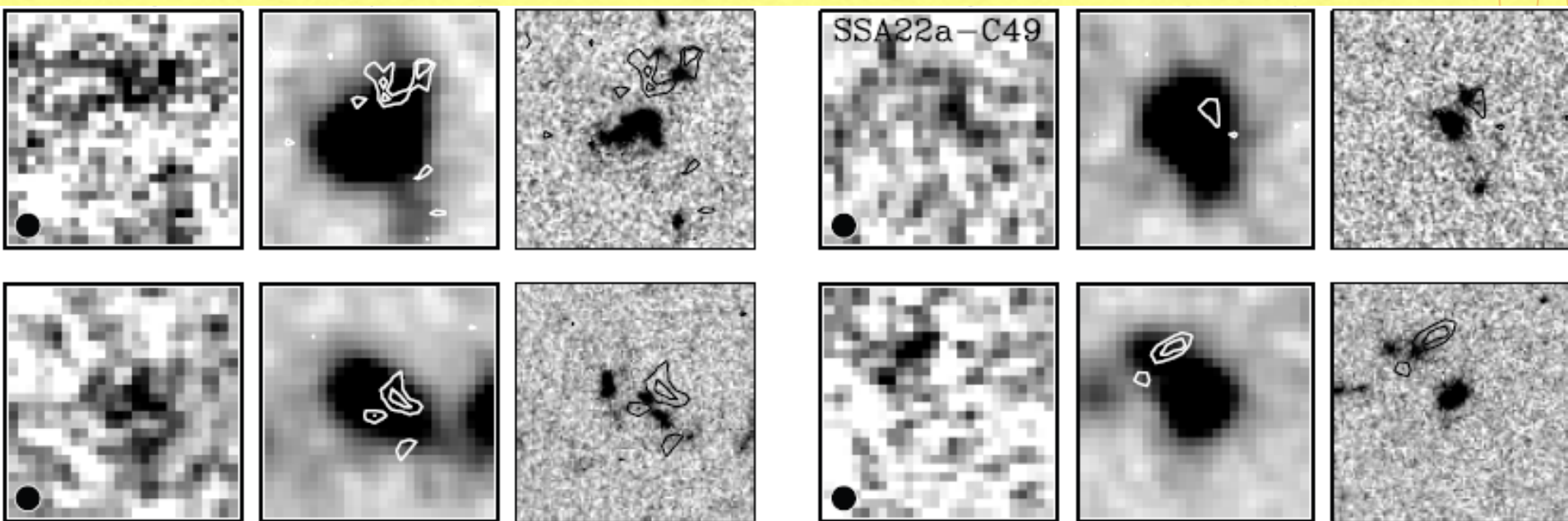
black points: median
error-bars: 68% range

red symbol:
Steidel et al.(2001)

LBGs: 7 detections out of 73!

- Significant offset between LyC and UV

NB359 (900A)	R (1500A)	ACS 814 (2000A)	NB359 (900A)	R (1500A)	ACS 814 (2000A)
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LAEs: 10 detections out of 125!

- Slight or no offset between LyC and UV

NB359
(900A)

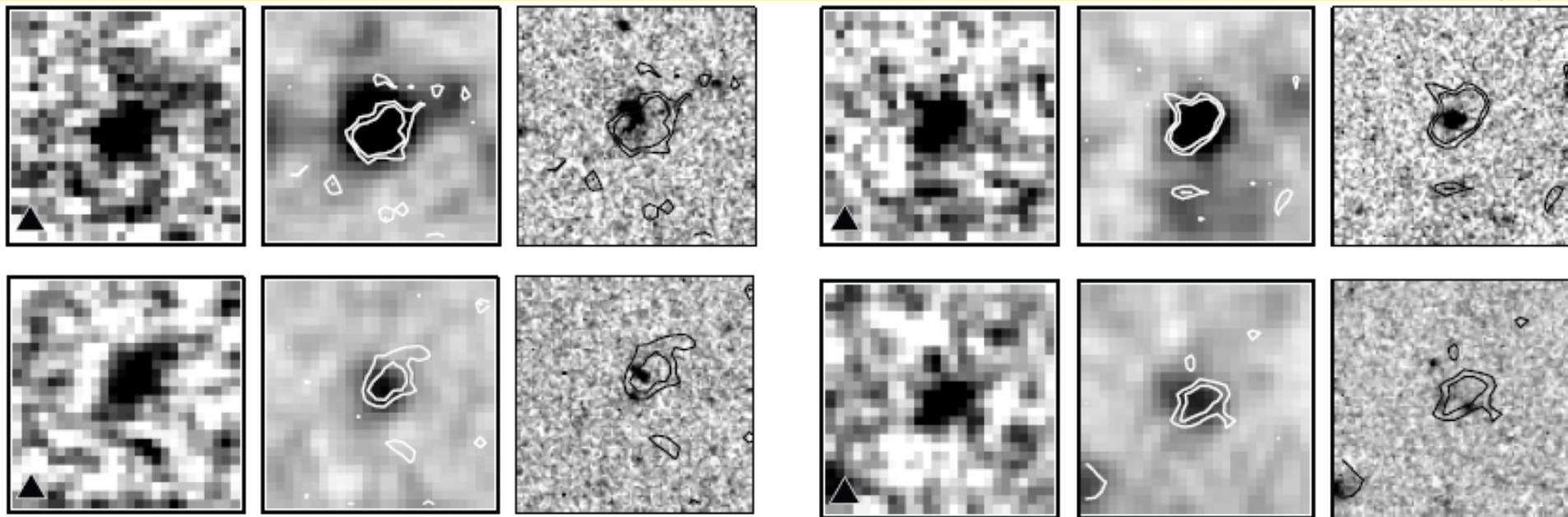
R
(1500A)

ACS 814
(2000A)

NB359
(900A)

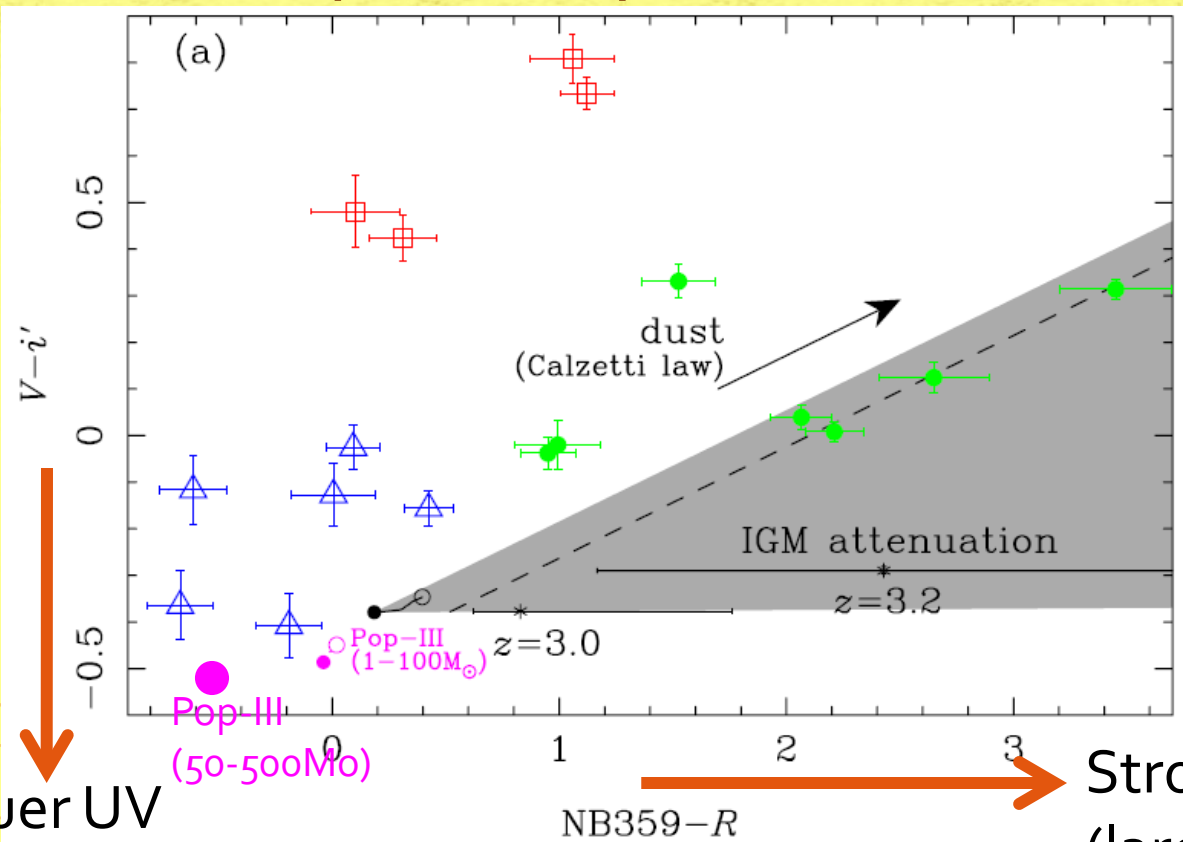
R
(1500A)

ACS 814
(2000A)



Rest-UV colors of LyC galaxies

- More LyC than predictions with Salpeter IMF!



green: LBGs
blue: blue-UV LAEs
red: red-UV LAEs

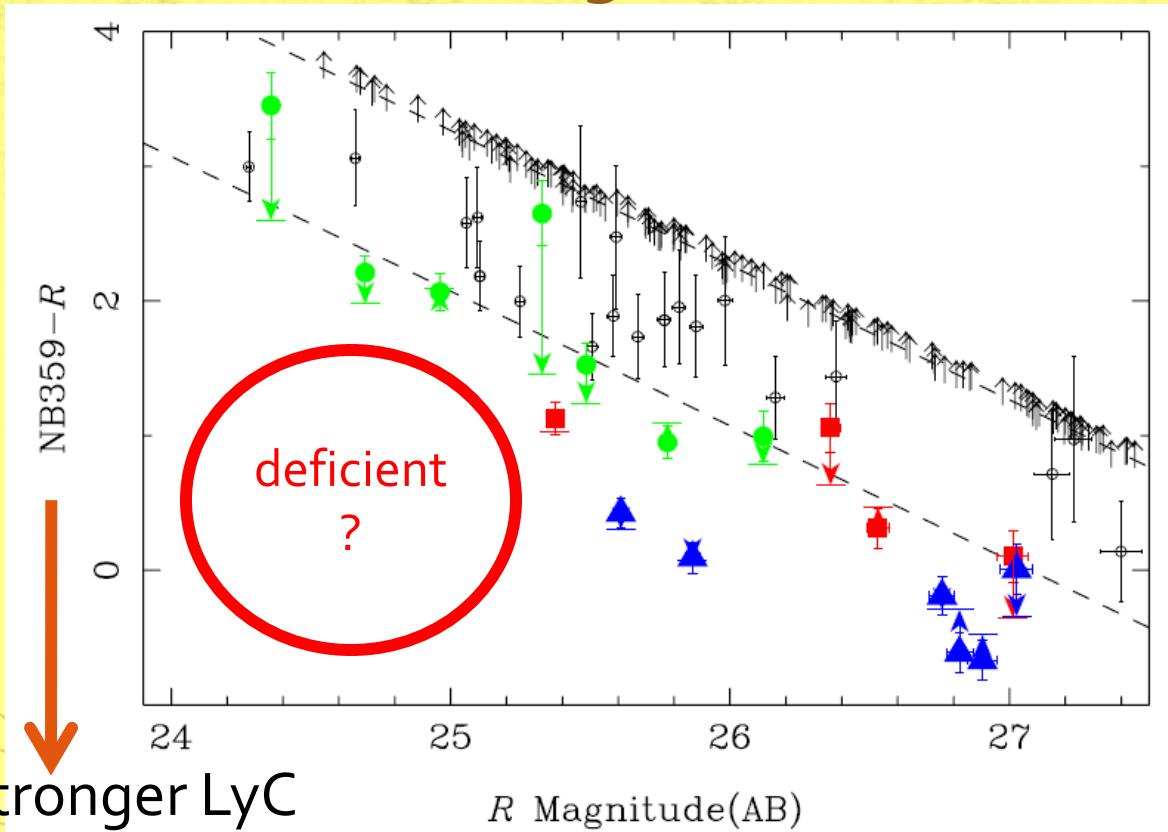
shaded area:
Salpeter IMF + dust
and IGM attenuation

Bluer UV
(younger age or smaller dust attenuation)

Stronger LyC
(larger escape fraction
or larger emissivity)

LyC-UV ratio vs. UV magnitude

- Less luminous galaxies emit stronger LyC!



green: LBGs
 blue: blue-UV LAEs
 red: red-UV LAEs

Note: NB359
 detection was made
 within 1."2 ap. but
 color was measured
 so as to be a total flux

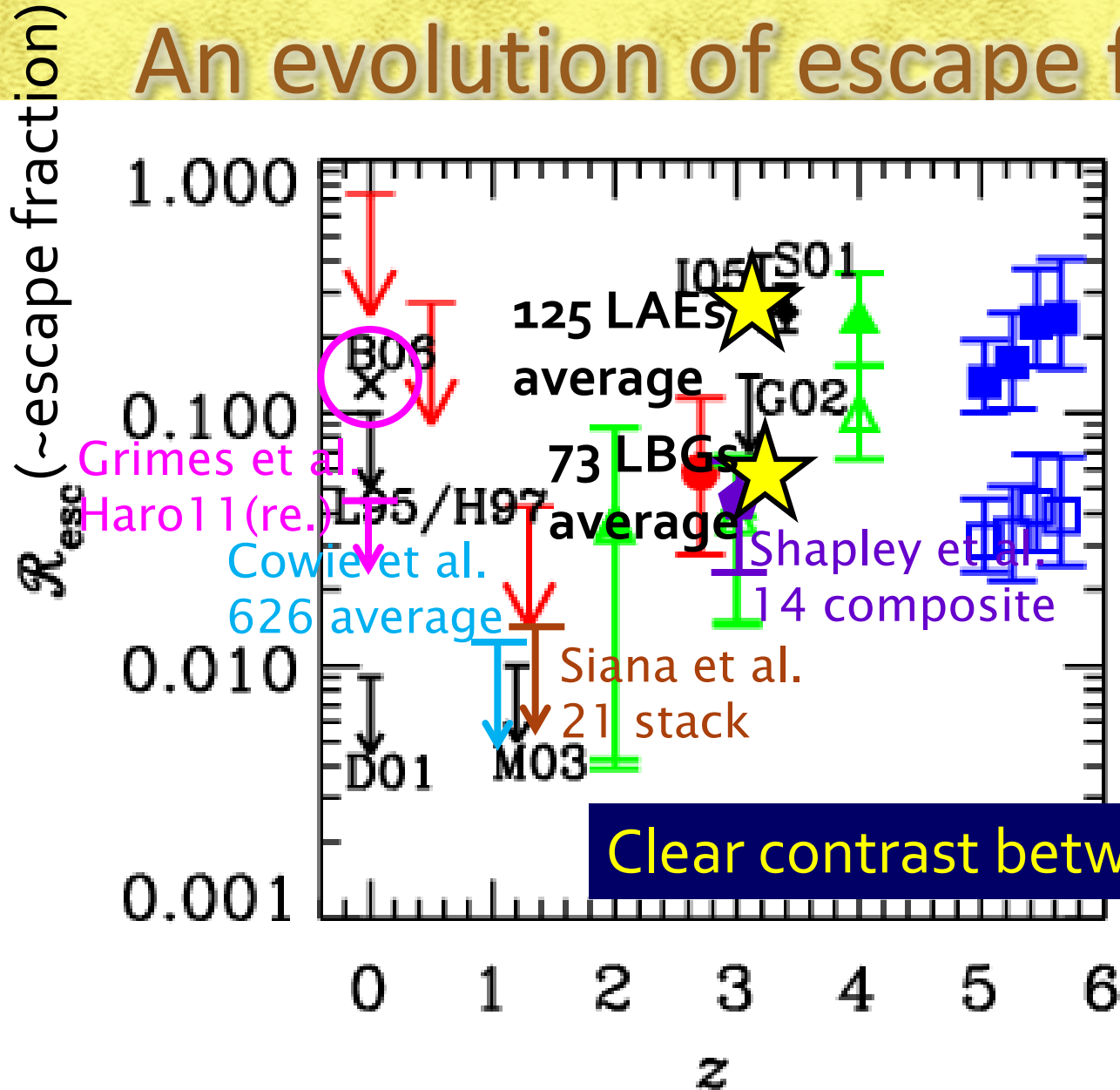
Stronger LyC
 (larger escape fraction or larger emissivity)

Escape fraction

Author	Sample	$(f_{1500}/f_{900})_{\text{obs}}$	fesc
Steidel+'01	29 LBGs, compo.	17.7	0.18
Shapley+'06	2 LBGs	12.7, 7.5	>0.09, >0.2
Shapley+'06	14 LBGs, compo.	58	0.041
Iwata+'09	7 LBGs	6.6 (2.5—23)	>0.2
preliminary	73 LBGs, ave.	69	0.047
Iwata+'09	10 LAEs	1.0 (0.5—2.8)	>1
preliminary	125 LAEs, ave.	13	0.25

NOTE: Escape fraction, fesc, is calculated from $(f_{1500}/f_{900})_{\text{obs}}$ with assumptions of $(f_{1500}/f_{900})_{\text{int}}=3.0$ and $A_{\text{UV}}=1.0$. The correction of the IGM opacity was applied only for composite or average values with the model by Inoue & Iwata (2008).

An evolution of escape fraction?



Red, green, and blue are obtained so as to reproduce the observed ionizing background by QSOs + galaxies (Inoue, Iwata, Deharveng 2006).

Clear contrast between $z < 1$ and $z > 3$!!!

Summary

- We performed a deep narrowband imaging with Subaru/Suprime-cam to search LyC from $z \sim 3$.
- We detected LyC from 17 galaxies among 198 galaxies with spectroscopic redshift $z \sim 3$.
- Average LyC escape fraction (or emissivity) of LBGs is consistent with that of Shapley et al.
- Less luminous LAEs emit stronger LyC. This may suggest that they are the cosmic “ionizer”.
- Further studies of LAEs’ LyC are very interesting.