

**An HSC Narrowband
survey: CHORUS**
**(Cosmic Hydrogen Reionization
Unveiled with Subaru)**

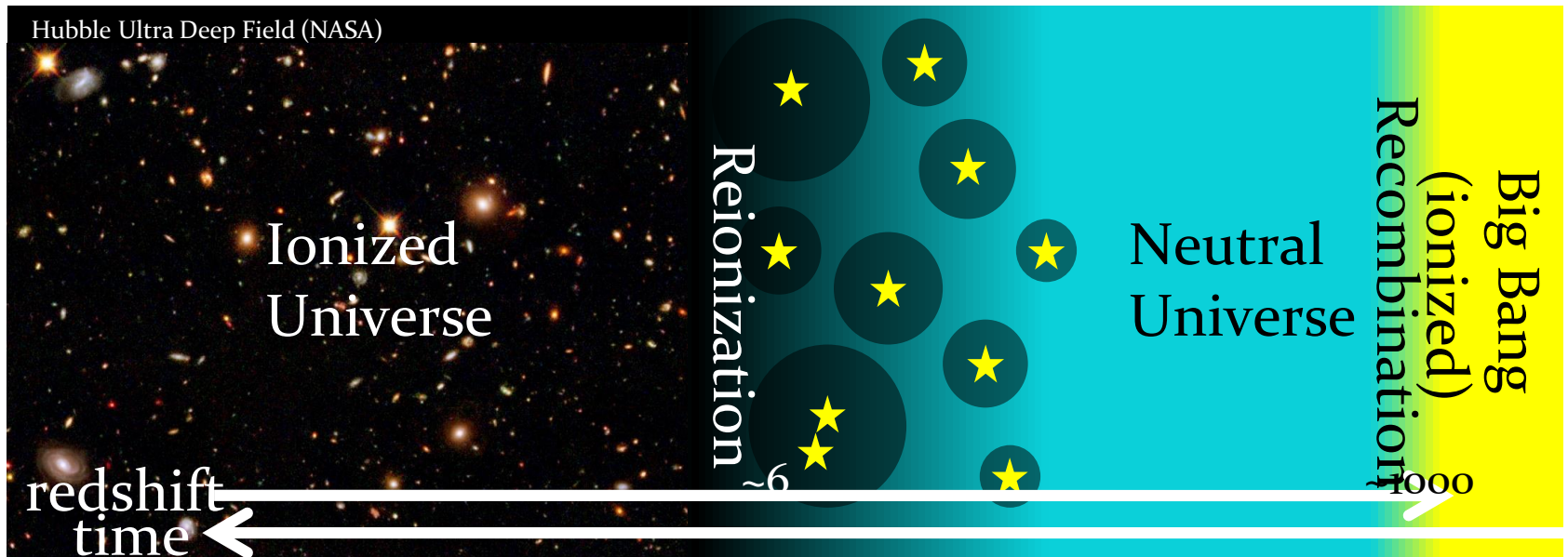
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(OSAKA SANGYO UNIVERSITY)

ON BEHALF OF CHORUS TEAM

REVEALING REIONIZATION

- **History**
 - **Sources**
 - **Topology**
- SSP LAE LF/ACF measurements
- 



STRATEGY

HSC-SSP UD

5 Broadband filters
(g, r, i, z, Y)
1 Narrowband NB921

There are two more NBs in SSP: NB816, NB101

5 Narrowband filters

NB387, NB527, NB718,
IB945, NB973

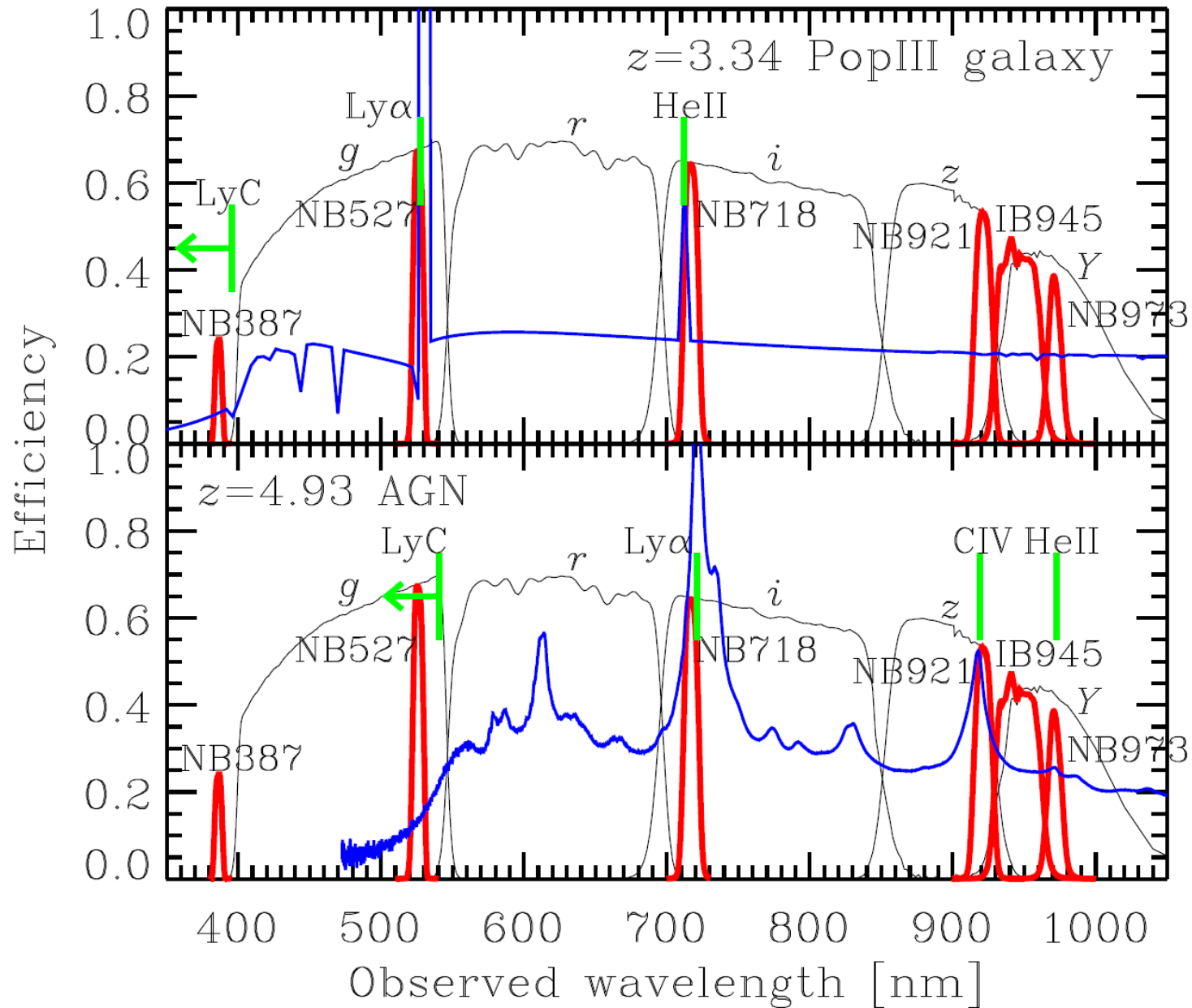
→ CHORUS

CHORUS FILTER SET

Filter	Developer	Budget source
NB387	K. Shimasaku (U. Tokyo)	JSPS Kakenhi
NB527	I. Iwata (NAOJ)	JSPS Kakenhi
NB718	Y. Taniguchi (Ehime U.)	MEXT
NB921 (SSP)	M. Ouchi (U. Tokyo)	JSPS Kakenhi
IB945	A. Inoue (Osaka S. U.)	JSPS Kakenhi
NB973	M. Ouchi (U. Tokyo)	JSPS Kakenhi

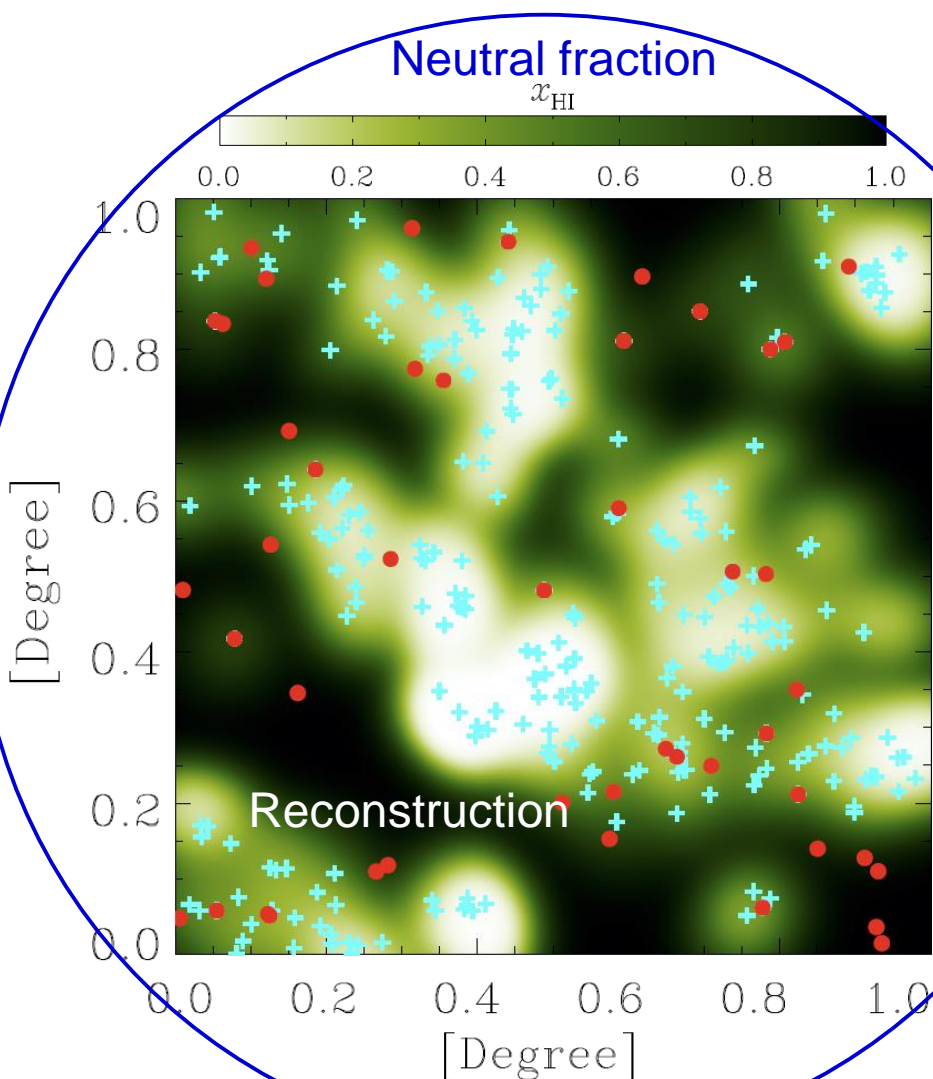
Coordinated by the HSC filter consortium
(and there are more)

CHORUS FILTER SET



VISUALIZATION OF HI DIST.

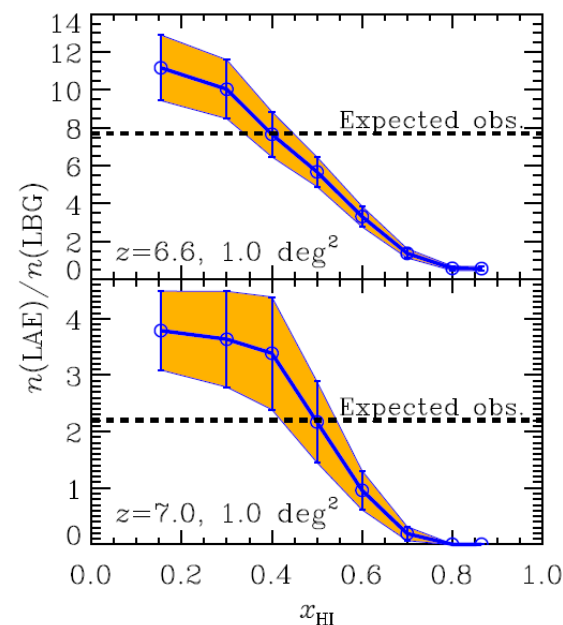
- LAE/LBG number ratio well correlates with the neutral hydrogen fraction.
- By using IB945, LBG selection tailored to LAE redshift can be realized.



Redshift	LAE selec.	LBG selec.
6.6	NB921	IB945, z, Y
7.0	NB973	IB945, z, Y

$z=6.6$
Cyan: LAE
Red: LBG

HSC
FoV

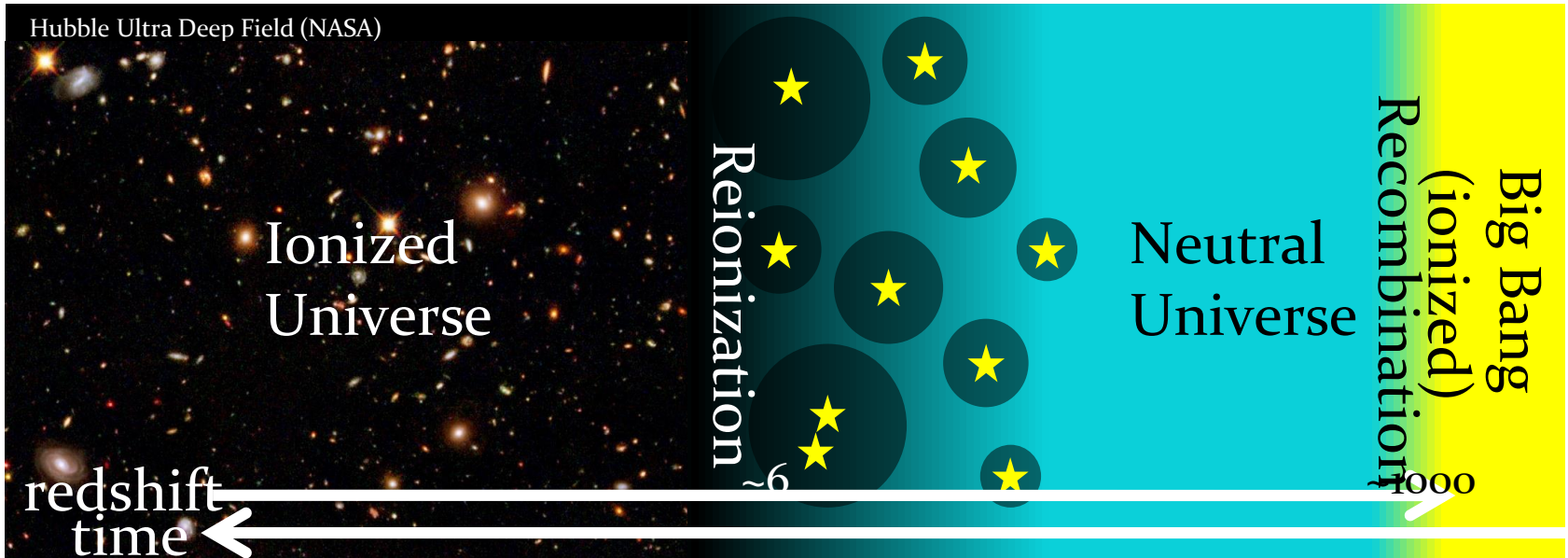


Assuming $x_{\text{HI}} - T_{\text{Ly}\alpha}^{\text{IGM}}$ (Jensen+13)

Color selection with photometric errors

REVEALING REIONIZATION

- **History**
 - **Sources**
 - **Topology**
- SSP LAE LF/ACF measurements
 - LyC measurements of galaxies and AGNs
 - Faint-AGN LF measurements
 - Pop-III SFRD measurements
 - Visualization of spatial distribution of xHI



OBSERVATIONS

- **S16B to S18A: 13 nights allocation for 1 HSC FOV → COSMOS**
- **S18B: additional 11.5 hours to complete the program**

Dates	Filter	Reports
Jan/26/2017 Jan/28/2017	NB973	~15 h data of COSMOS (+ ~5 h of SXDS UD)
Feb/25/2017	NB718	No meaningful data due to thick clouds
Mar/23/2017 Mar/25/2017	NB718	~6 h data of COSMOS (+ 40min each for 4 points in ELAIS-N1 D)
Dec/16-18/2017	NB527	Almost cloudy, 0.5 h data of COSMOS
Jan/17-19/2018	NB387	~21 h data of COSMOS but seeing ~1.2 arcsec
Mar/15, 16, 18/2018	NB527	~10 h data of COSMOS (seeing ~1 arcsec)
Dec/2018 0.5n+11.5h	IB945	~10h data of COSMOS (seeing ~0.7 arcsec)

LIMITING MAGNITUDES

Preliminary reduction (hscPipe ver.4)

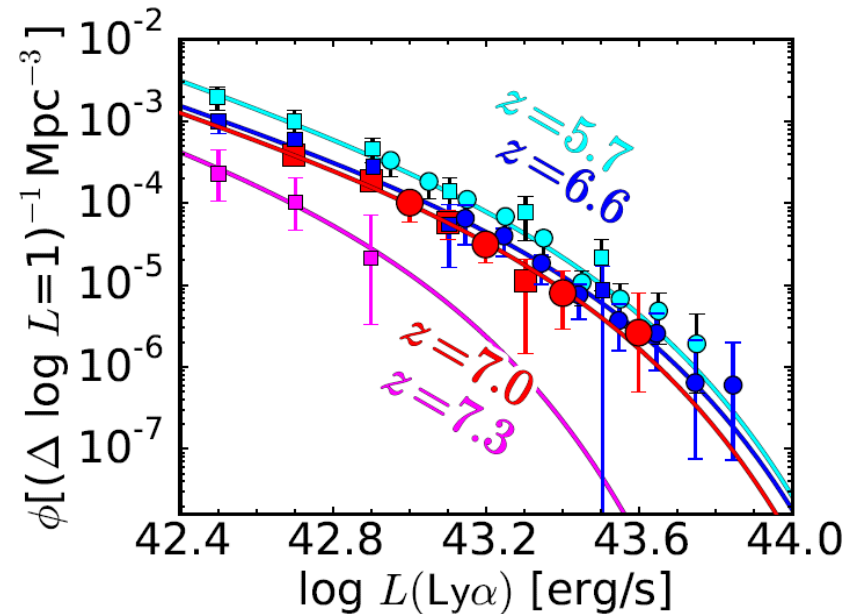
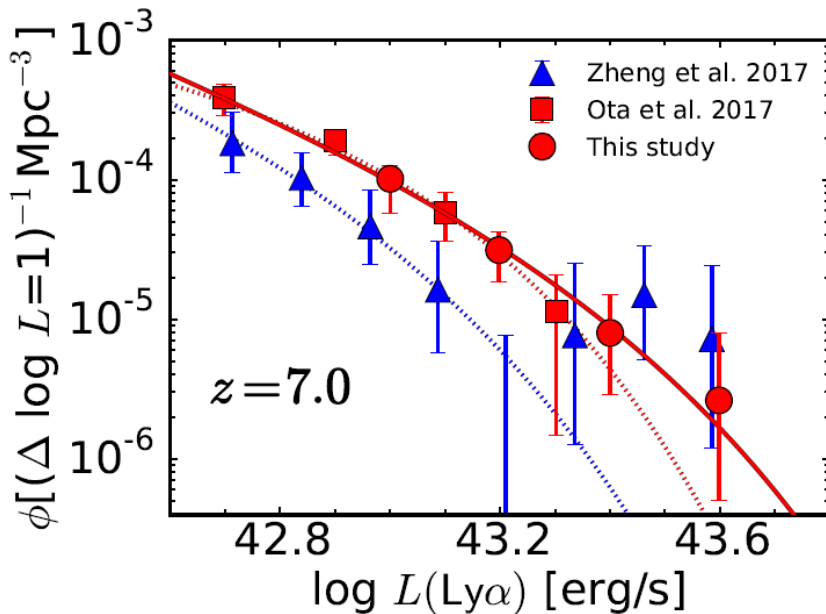
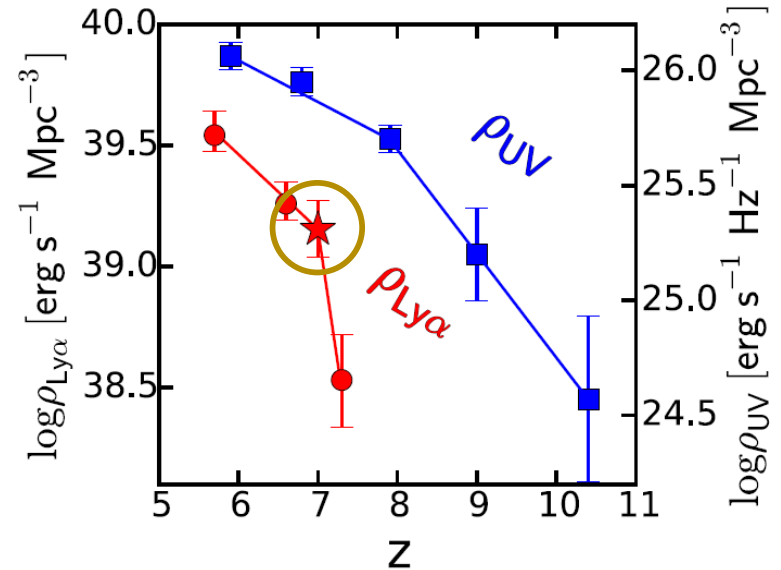
Filter	Request ($5\sigma, 2''$) [AB]	Usable exposure [sec]	ETC (*) ($5\sigma, 1.5''$) [AB]	Achieved ($5\sigma, 1.5''$) [AB]	PSF size [arcsec]	Remarks
NB387	26.8	61,200	27.17	26.7	1.03	T9813, P(4,4)
NB527	27.5	32,361	27.60	26.8	0.83	T9813, P(4,4)
NB718	26.8	27,600	27.12	26.2	0.69	COSMOS
IB945	26.2	-	-	-	-	Just observed
NB973	25.6	52,800 (16,800)	25.90 (25.27)	24.9 (24.2)	0.64 (0.78)	COSMOS (SXDS)

- There is a spatial variation of the limit. mag. and PSF in the FoV.
 - SSP S18A (hscPipe ver.6) catalog for 4NBs is to be validated.
 - 0.5-1 mag shallower than ETC.
 - M1 reflectivity degrade was ~40% ? Sky model in ETC is too optimistic ?
- (*) Dark, transparency 0.9, seeing 0.7", point source
(The seeing value does not change the ETC results, why?)

SCIENCE RESULTS #1

R. Itoh (U. Tokyo) et al. ApJ

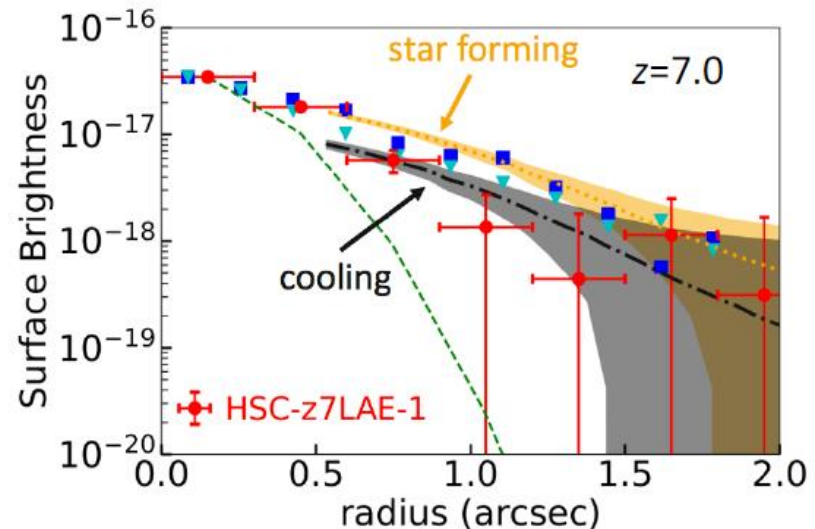
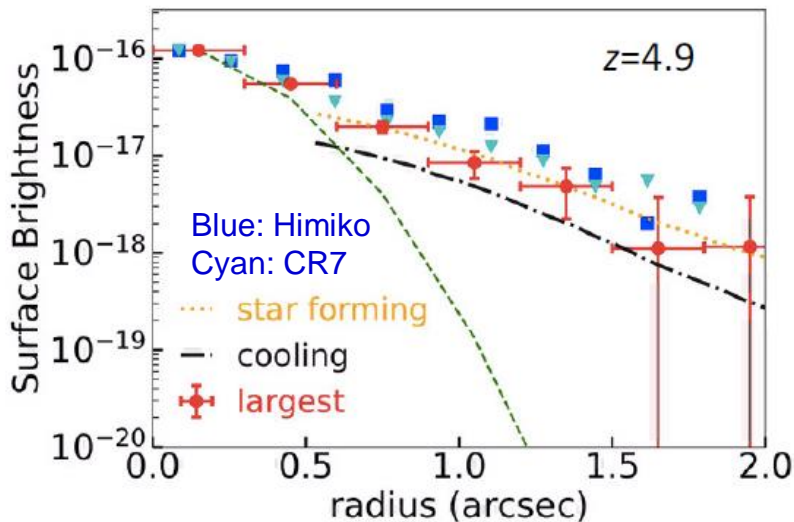
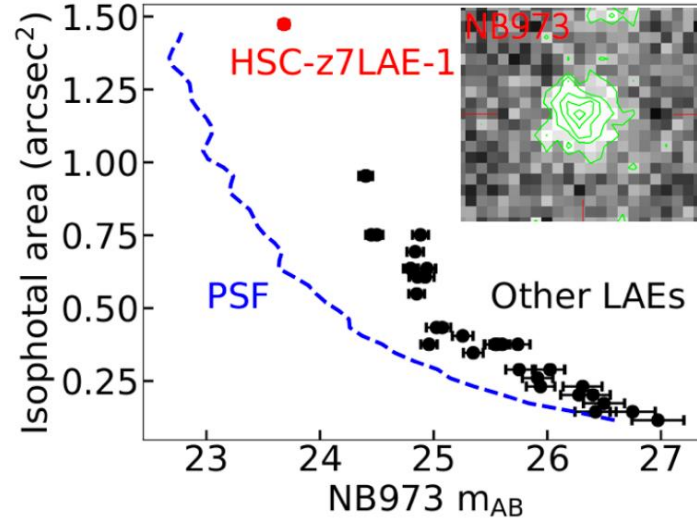
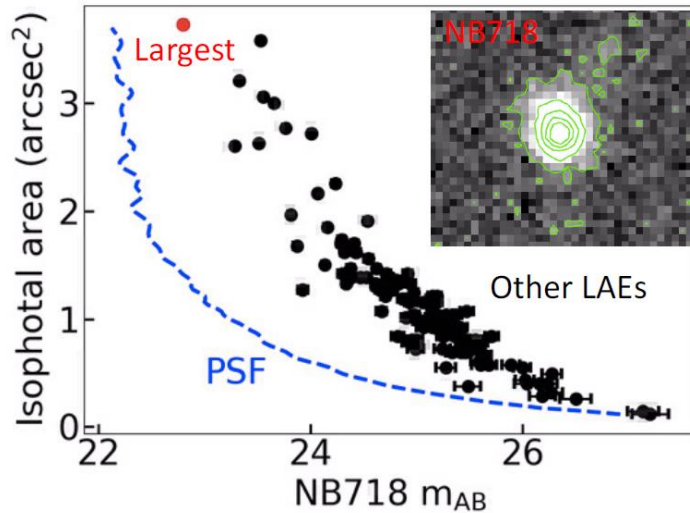
- LAE luminosity function at $z=7.0$ (NB973)
- A rapid decline of the LAE LF and LyA luminosity density between $z=7.0$ and $z=7.3$.



SCIENCE RESULTS #2

H. Zhang (U. Tokyo) et al. in prep.

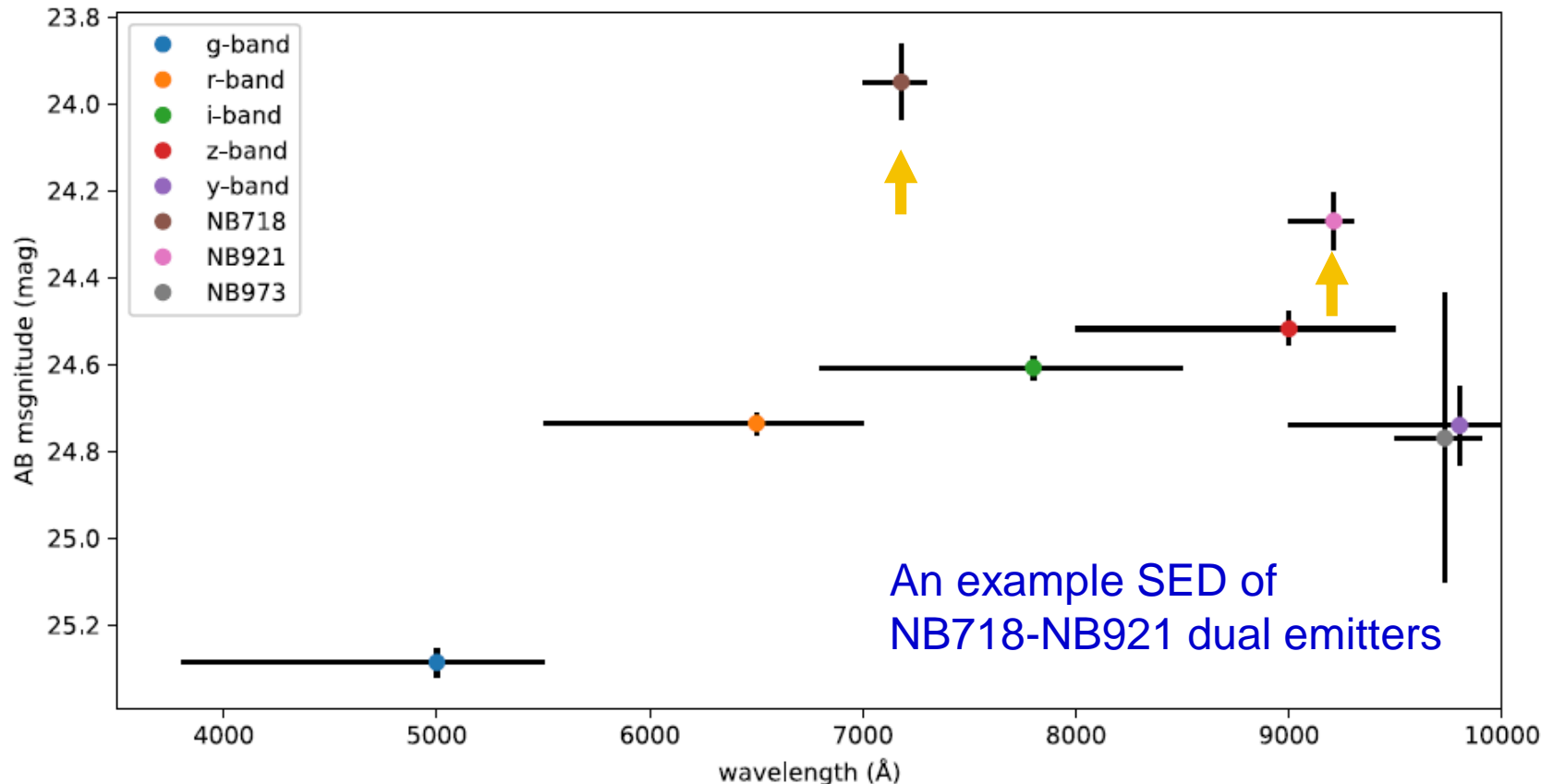
- Ly α blobs at $z=4.9$ and $z=7.0$.



SCIENCE RESULTS #3

K. Iwashita (Ehime U.) et al. in prep.

- Dual emitter search
 - 4 NB718-NB921 dual emitters (preliminary)
 - $z=4.9$ LyA-CIV AGN candidates



SUMMARY

- **CHORUS observations have been completed.**
 - The last filter, IB945, data delivery will happen soon hopefully.
- SSP S18A version NB387, NB527, NB718 and NB973 photometric catalogs will become available in HSC database as soon as possible.
 - IB945 β -reduction will be done by the team as soon as possible.
- The achieved limiting magnitudes are 0.5-1 mag shallower than those expected by ETC.
 - M1 reflectivity ? and/or optimistic sky ?
- **Early science results are coming up:**
 - LAE luminosity functions at $z=7.0$ <published>
 - LABs at $z=4.9$ and $z=7.0$
 - LyA-CIV dual emitters at $z=4.9$
- **Using the NB photometry on the HSC database, just send us an e-mail, if you are a member of the HSC SSP.**
 - Non-members? Please contact us to start a collaboration.

BACKUP

LYC EMISSIVITY OF GALAXIES

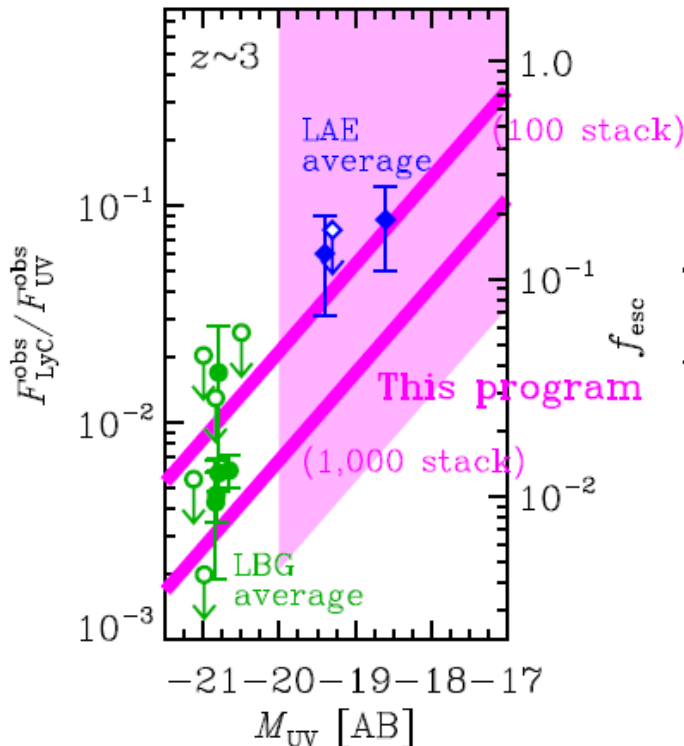
JWST target

Redshift	LyC	Ly α	# of obj.
3.3	NB387	NB527	~10k
4.9	NB527	NB718	~6k

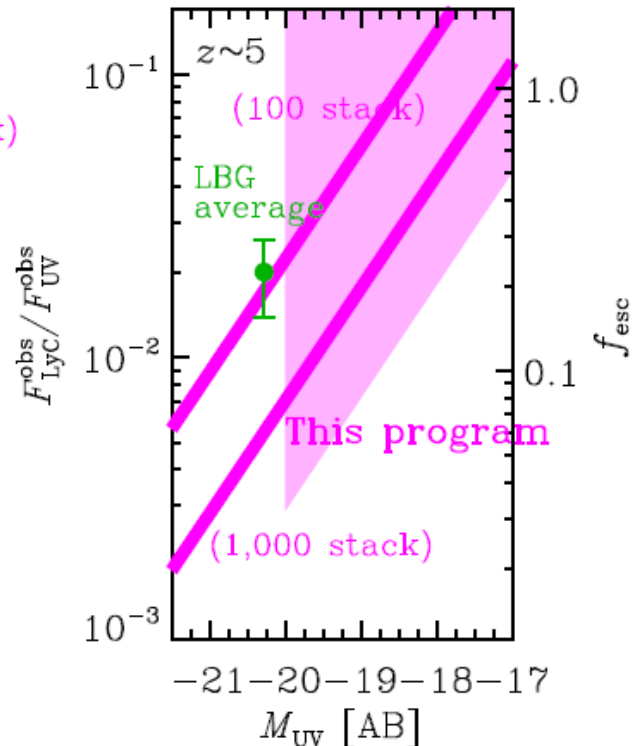
For 2
HSC
FOVs

Individual detections (~40@z~3, ~10@z~5) → Characterize of LyC emitters
Average LyC emissivity of LAEs → Galaxies' role in reionization

LyC(900A)/UV(1500A)
observed ratio



UV absolute mag.



UV absolute mag.

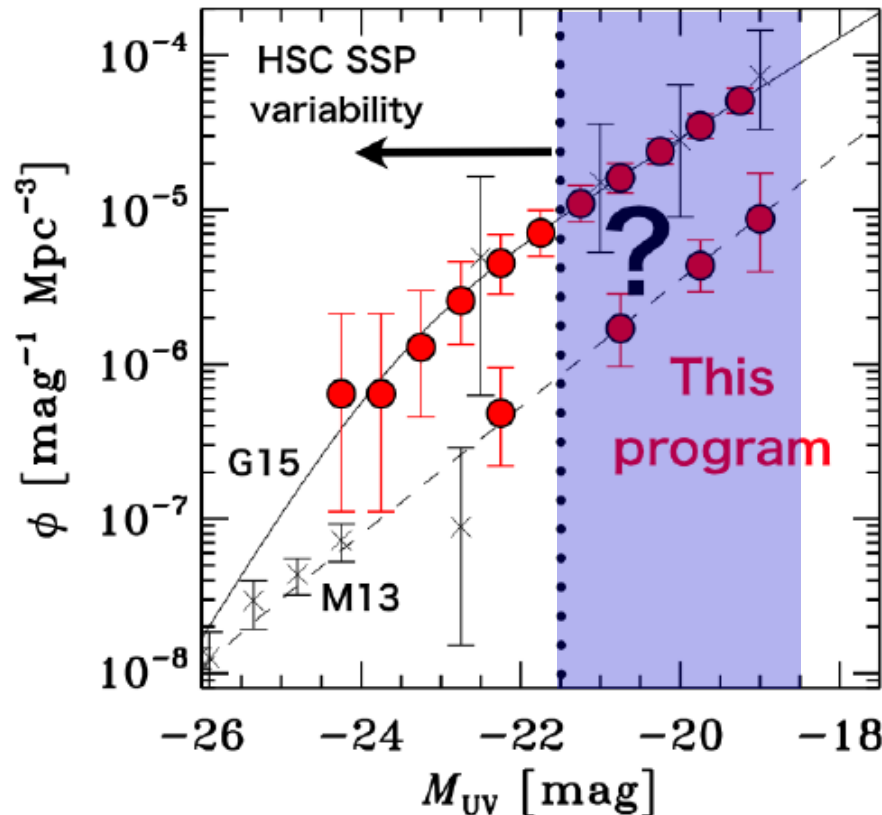
Average escape fraction

FAINT-AGN LF

For 2
HSC
FOVs

Faint-AGN = Ly α -CIV dual emitters

Redshift	LyC	Ly α	CIV	Offband	Hell
4.9	NB527	NB718	NB921	IB945	NB973



If Giallongo+15 LF is correct, only AGN can complete reionization.

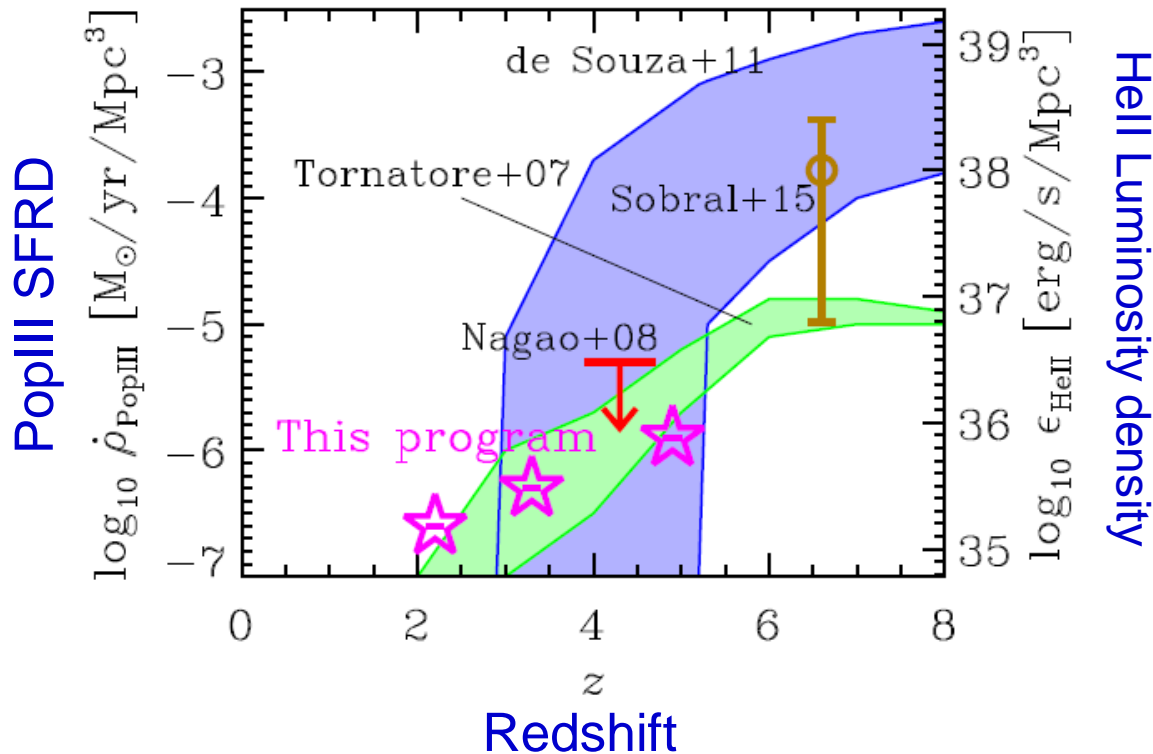
- 2.5 mag fainter AGNs than the SSP's variability survey can be detected.
 - Direct measure of LyC from AGNs
- ⇒ Revealing the role of faint-AGNs in reionization.

POP-III ABUNDANCE

For 2
HSC
FOVs

Pop-III galaxy candidates = Ly α -HeII dual emitters

Redshift	Ly α	Offband	HeII	SFR lim.[Mo/yr]
2.2	NB387		NB527	0.15
3.3	NB527		NB718	0.48
4.9	NB718	IB945	NB973	1.7



JWST spectroscopy
for candidate objects
→ Pop-III IMF

There are contamination
of AGN and WR stars in
the detected Ly α -HeII dual
emitters.