

遠方銀河に関するHST, Subaru, ALMAの最近 の成果と将来展望



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もくじ



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 - ☞ 最遠方LBG
2. Subaru, Keck, VLTの成果
 - ☞ 最遠方LAE
 - ☞ Ly α halo
 - ☞ HI Cosmic Web
 - ☞ CGM
 - ☞ CIII]1909輝線
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4. 将来展望
 - ☞ Subaru/HSC NB探査
 - ☞ Subaru/PFS HI 3D mapping
 - ☞ 2020年代のUV光度関数

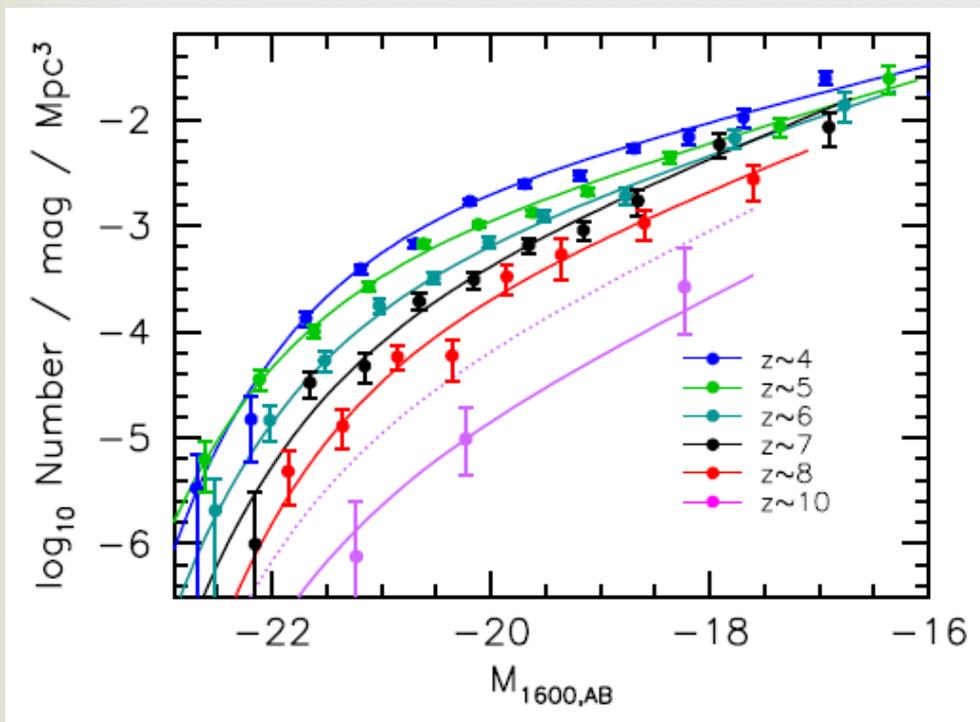
遠方銀河に関する HSTの成果



最遠方LBG (Bouwens+15, Finkelsteil+15, Ishigaki+15, Song+15,
Huang+15)

Bouwens+15

HST/WFC3



⌘ HST/WFC3 surveys

⌘ XDF, HUDF, CANDELS, BoRG

⌘ $\sim 1000 \text{ arcmin}^2$

⌘ Lyman break technique

⌘ $z \sim 4$ 5859

⌘ $z \sim 5$ 3002

⌘ $z \sim 6$ 857

⌘ $z \sim 7$ 481

⌘ $z \sim 8$ 217

⌘ $z \sim 10$ 6

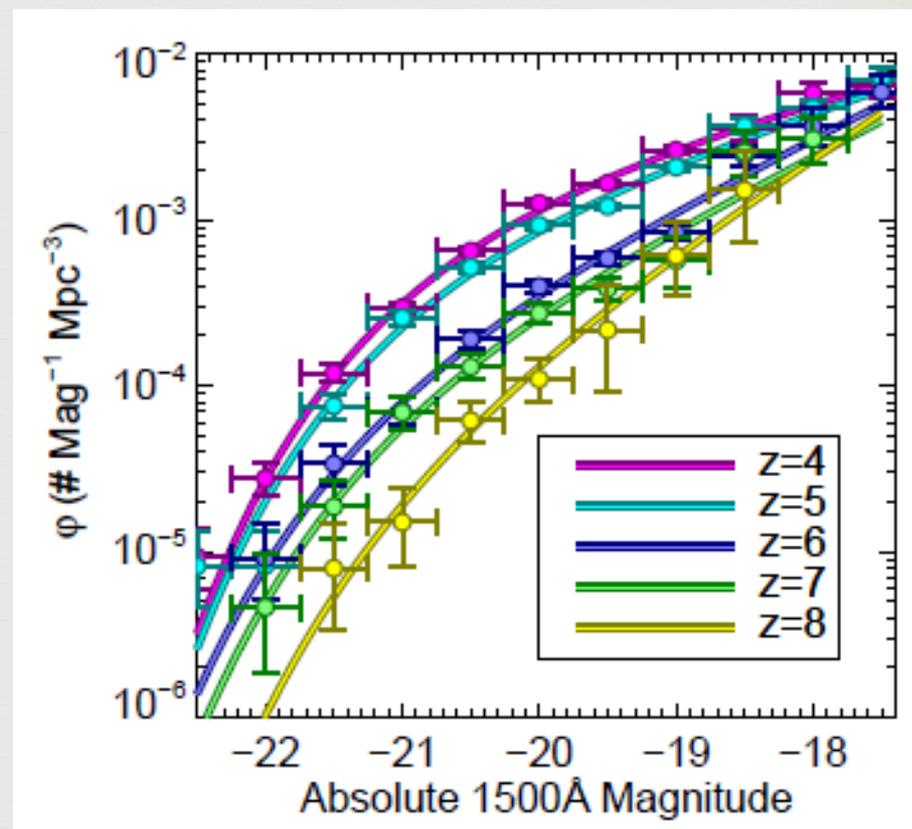
Finkelstein+15

HST/WFC3



- ❧ HST/WFC3 surveys
 - ❧ HUDF, CANDELS, HFF-PAR
 - ❧ $\sim 300 \text{ arcmin}^2$
- ❧ Photometric redshift

❧ z~4	4156
❧ z~5	2204
❧ z~6	706
❧ z~7	300
❧ z~8	80

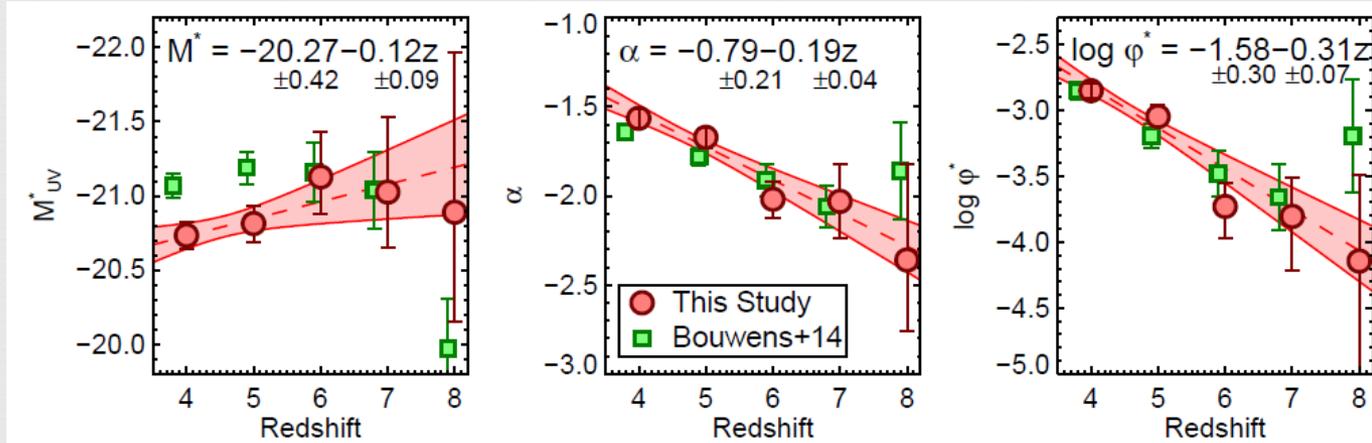


Evolution of LF parameters

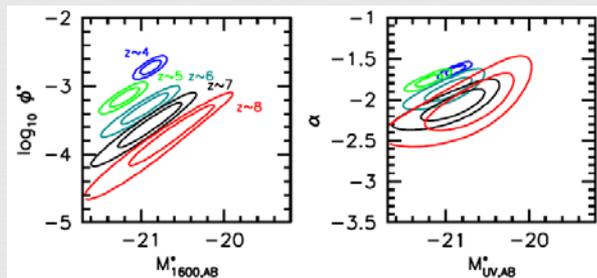
HST/WFC3



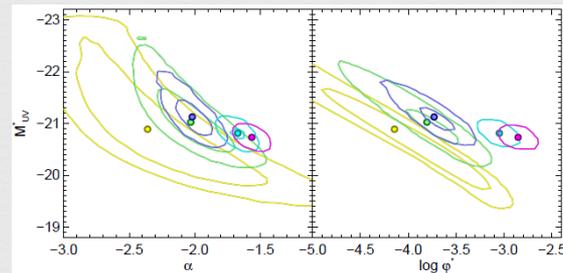
Roughly constant M^* , decreasing ϕ^* and α



F+15



B+15



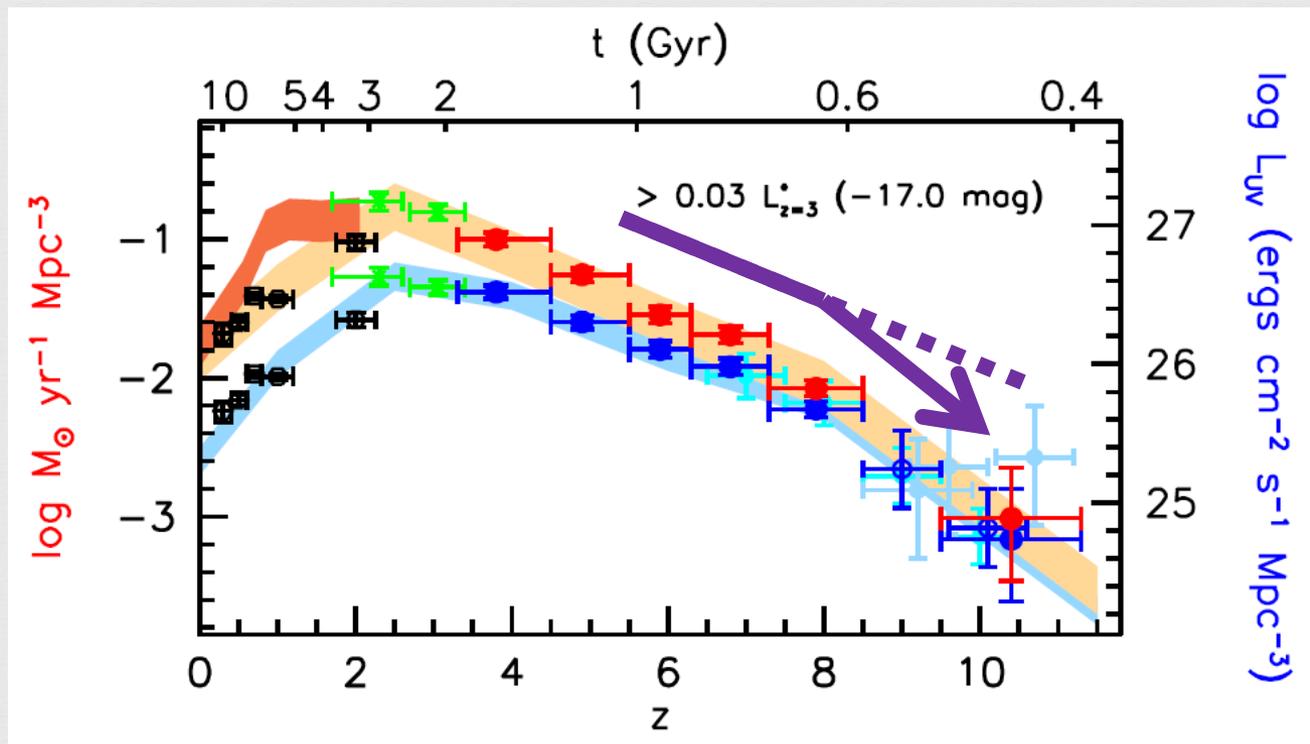
F+15

Cosmic SFRD evolution

HST/WFC3



☞ Break at $z \sim 8$?



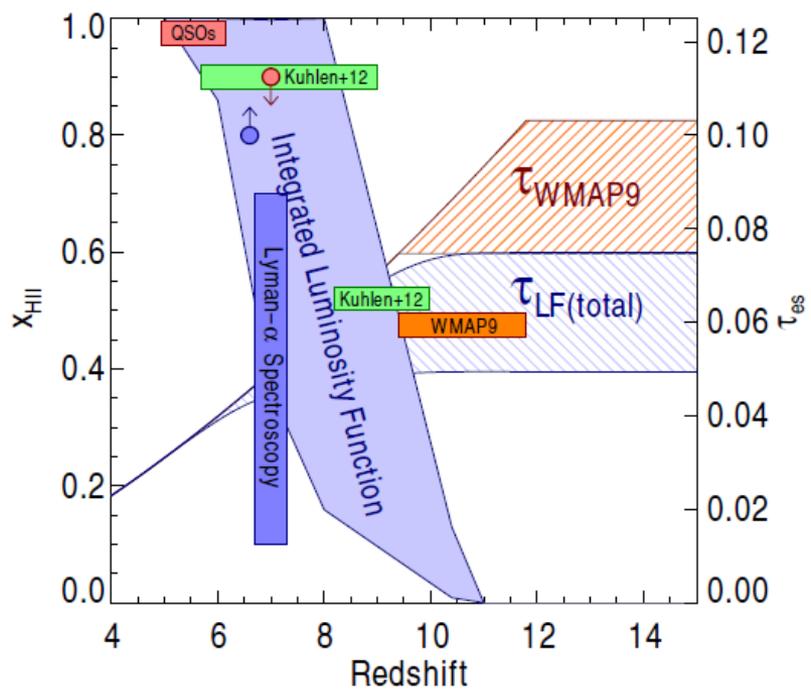
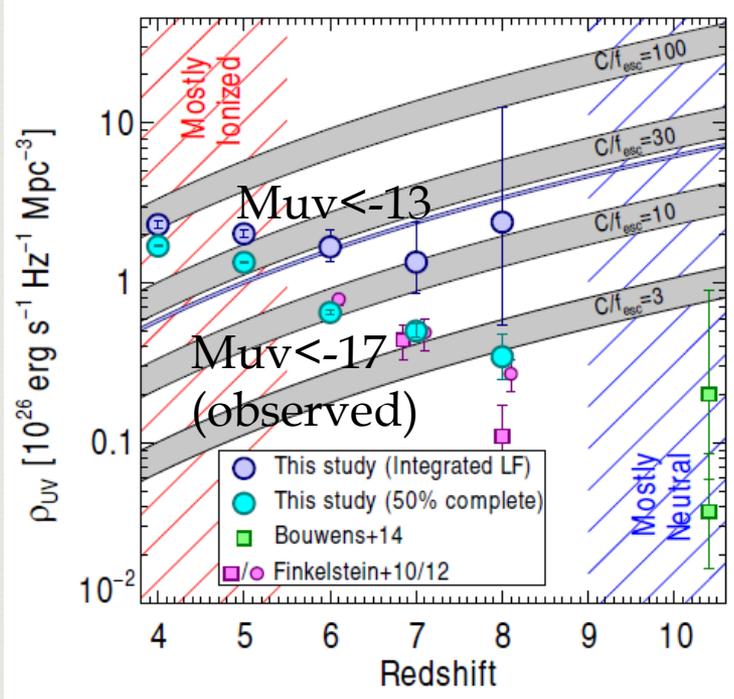
B+15

Reionization?

HST/WFC3



OK? if, for example, $M_{UV} < -13$, $f_{esc} = 0.13$, $C = 3$



F+15

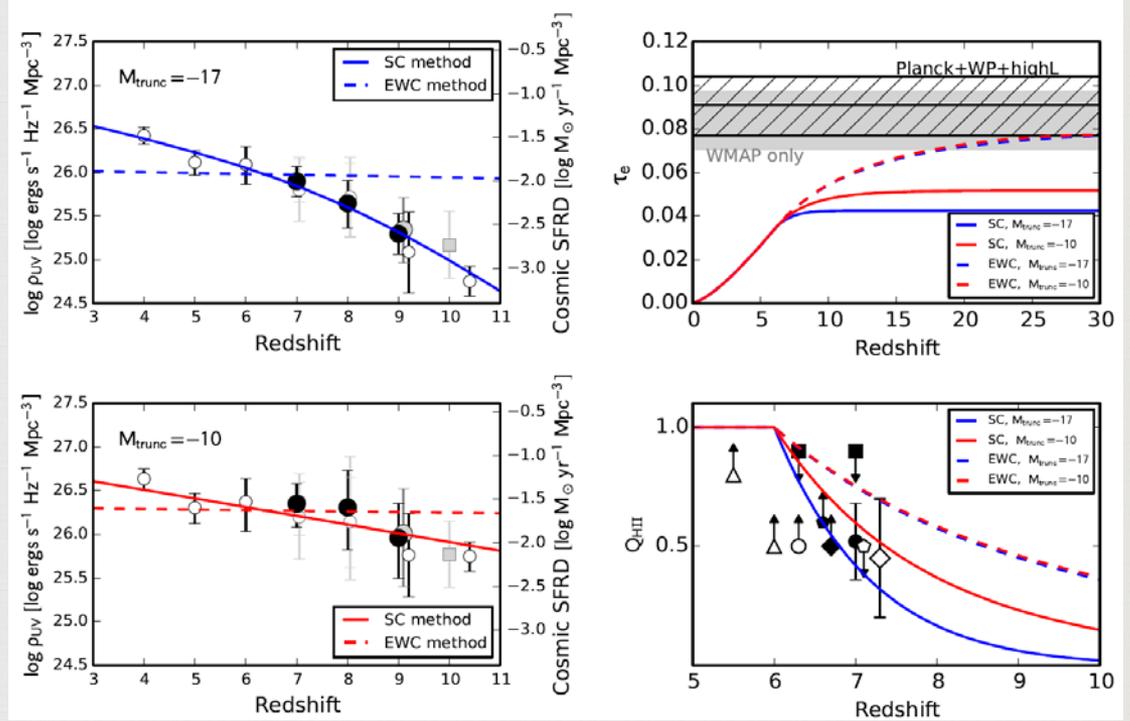
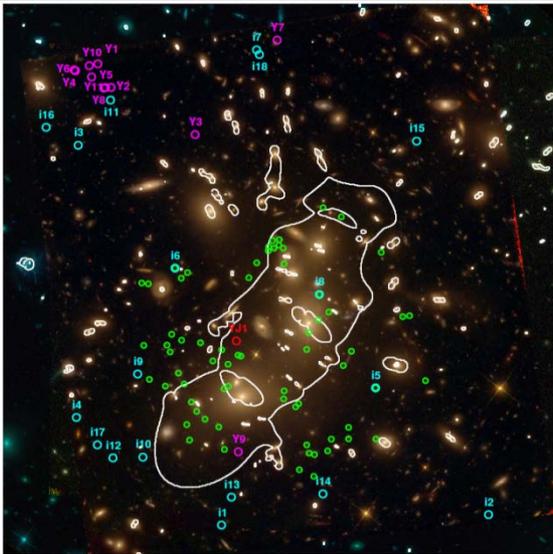
Ishigaki+15

HST/WFC3



A tension between UV luminosity density and CMB optical depth?

Abell 2744 (z=0.308)



Song+15 (in prep.)

HST/WFC3
Spitzer/IRAC



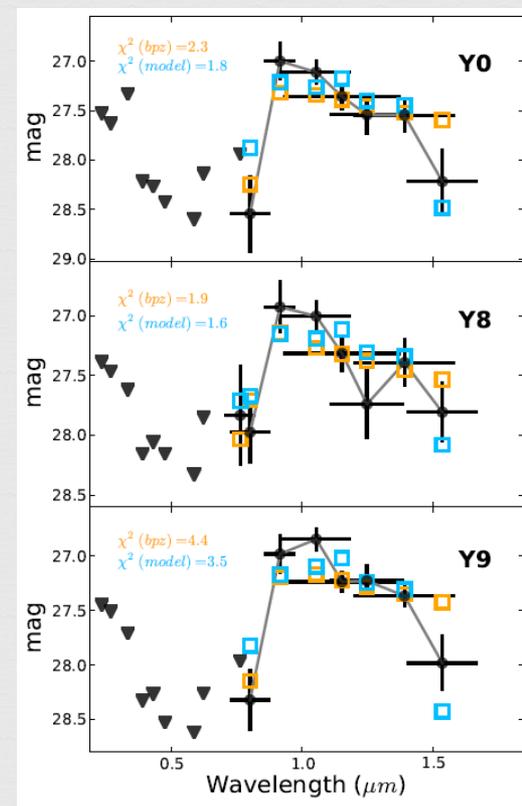
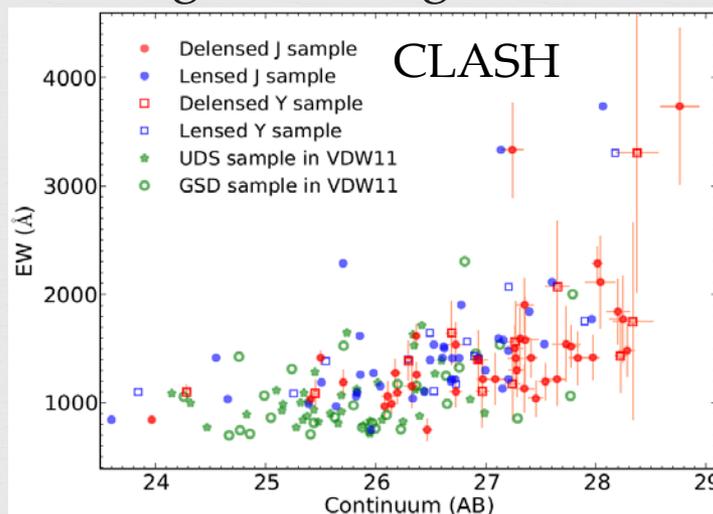
- ☞ S-CANDELS data -> Stellar mass function up to $z \sim 8$
 - ☞ ~27AB at 3.6 micron
 - ☞ Weak M^* evolution
 - ☞ Rapid decline at $z \sim 8$

Huang+15



HST/WFC3

- ☞ Extreme [OII], [OIII], H α emitters at $z \sim 1-2$ may contaminate high- z LBGs.
- ☞ $\sim 1\%$ for $z \sim 6$ LBGs
- ☞ Much higher for higher- z LBGs?



遠方銀河に関する Subaru, Keck, VLTの成果



最遠方LAE (Konno+14, Tilvi+14,)

$\text{Ly}\alpha$ halo (Momose+14, Cantalupo+14)

HI Cosmic Web (Lee+14)

CGM (Turner+14, Prochaska+14, Diaz+14,15)

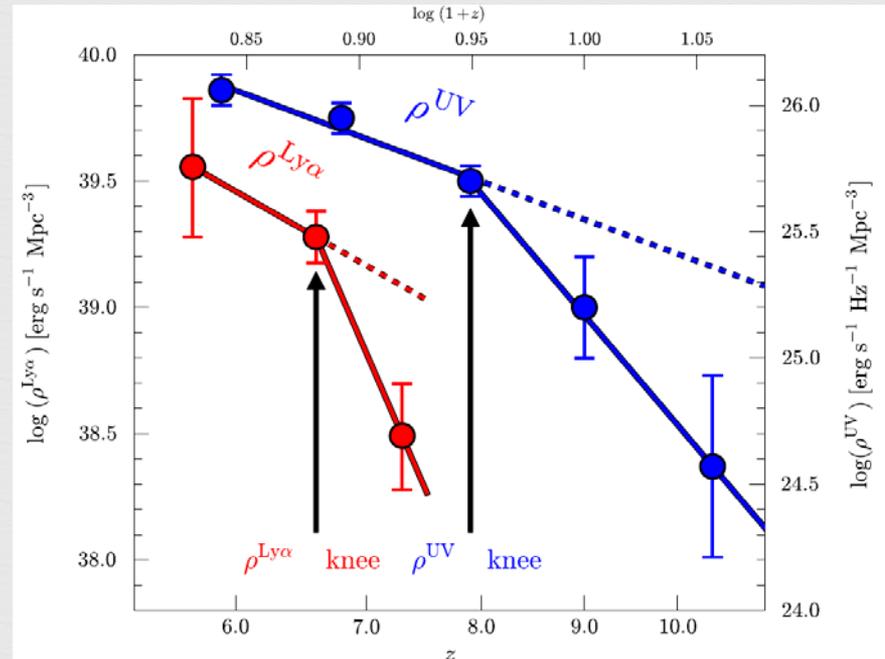
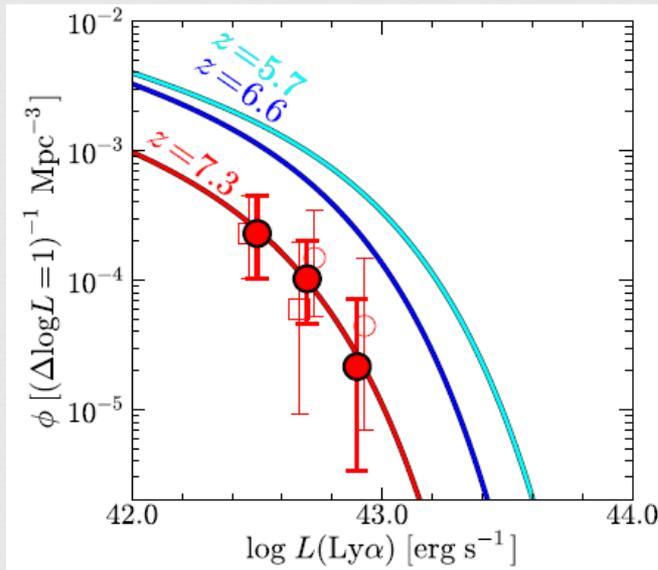
CIII]1909輝線 (Stark+14,15)

Konno+14

Subaru/S-Cam



- More rapid decline of LAE luminosity function
- Clumpy HI clouds in ionized bubbles?



Tilvi+14

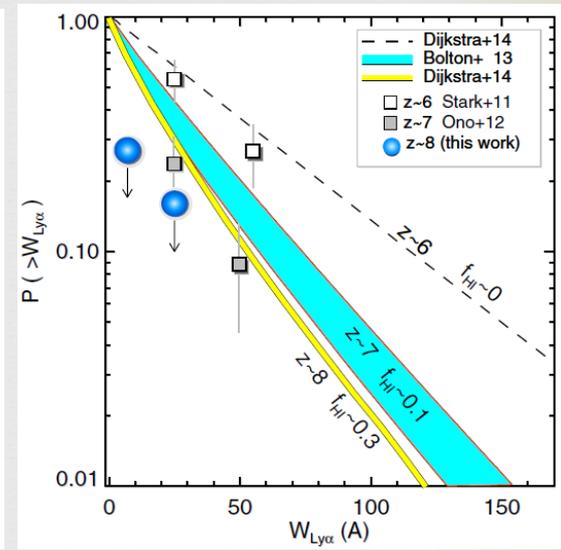
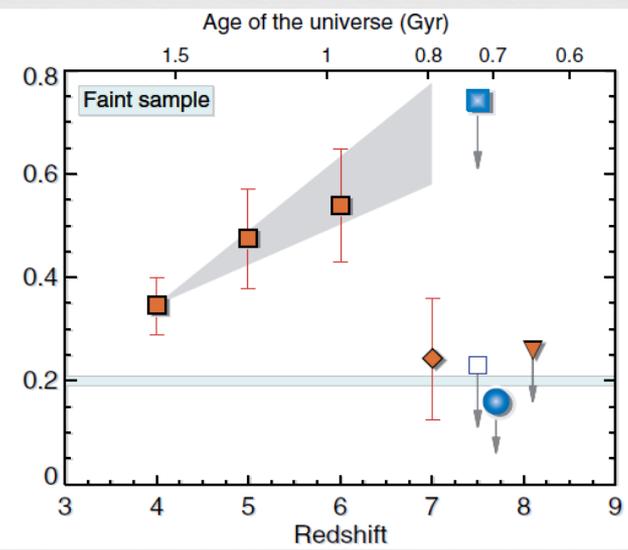
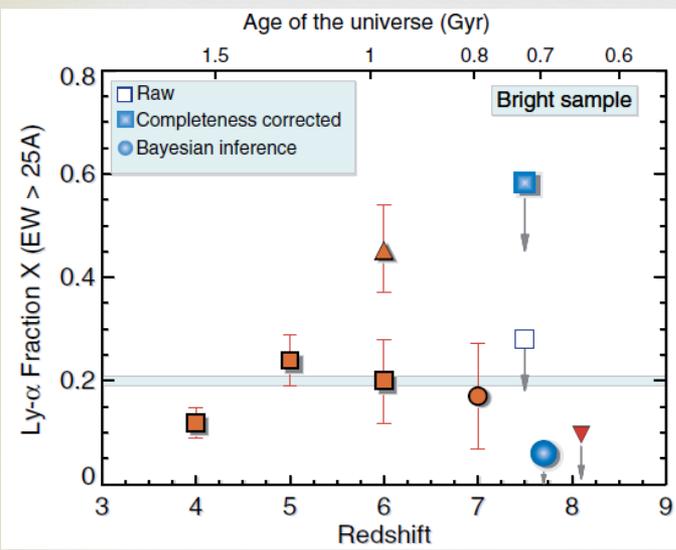


Keck/MOSFIRE

☞ LAE fraction in LBG

☞ 9 photo-z~8 from CANDELS -> No Ly α detection

☞ Number ev. is weakly more favored than dimming ev.

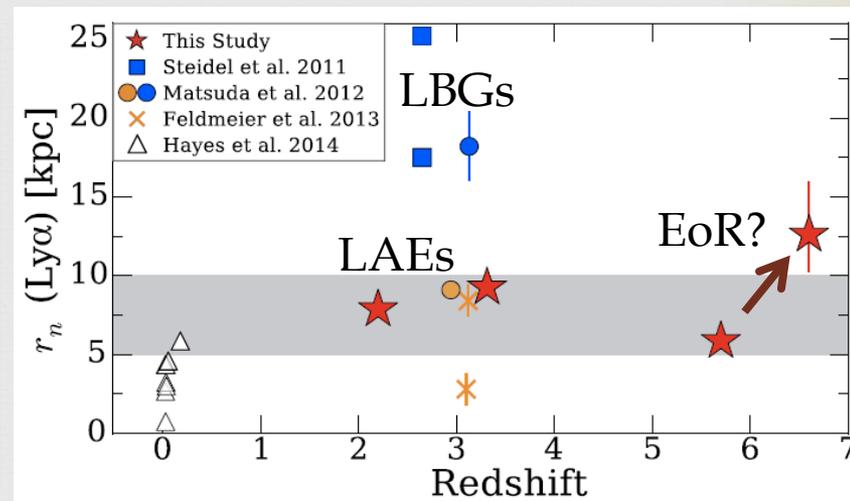
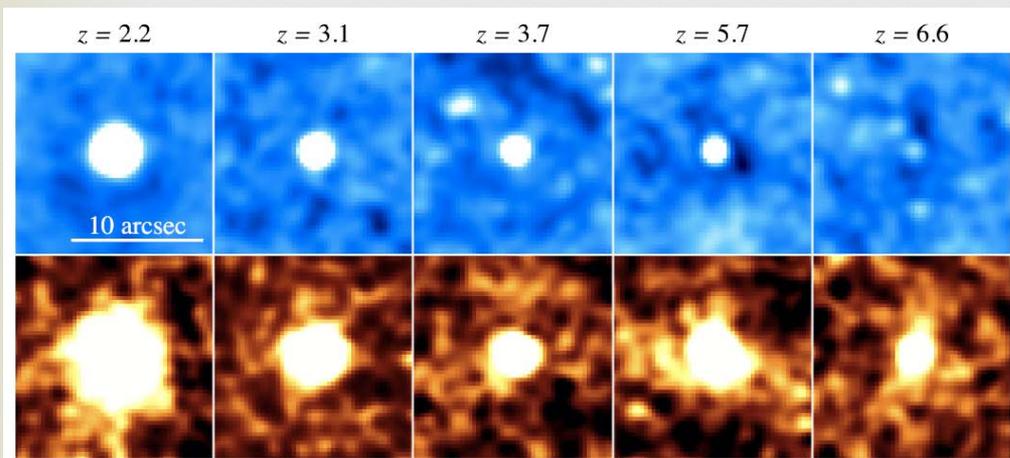


Momose+14

Subaru/S-Cam



- ☞ Ly α emitting halo around LAEs at $z \sim 2$ to ~ 7
- ☞ Extended Ly α halo: $r_{\text{Ly}\alpha}/r_{\text{cont}} = 5 - 10$
- ☞ Larger size at $z \sim 6.6$ may be a reionization signature.

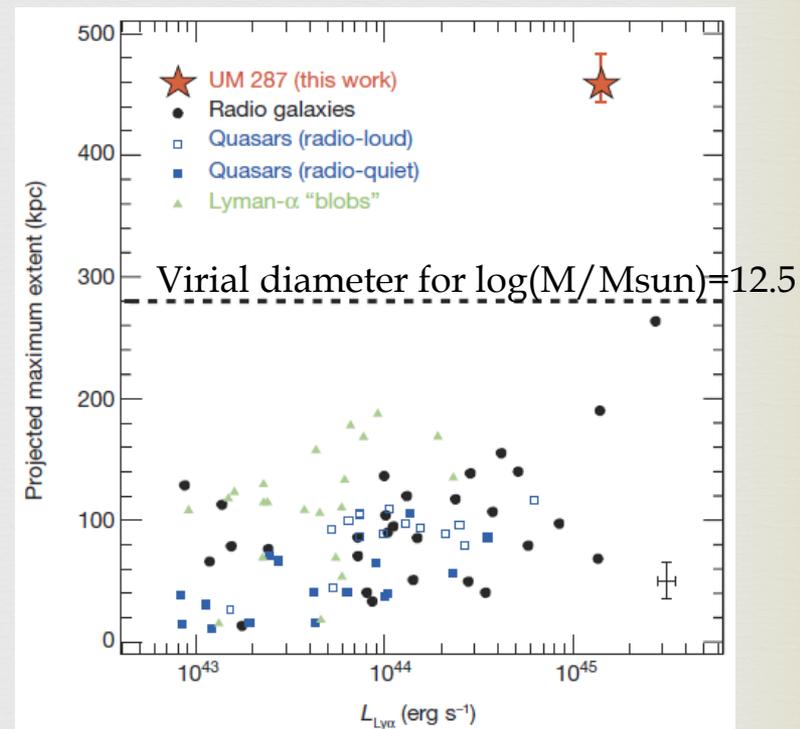
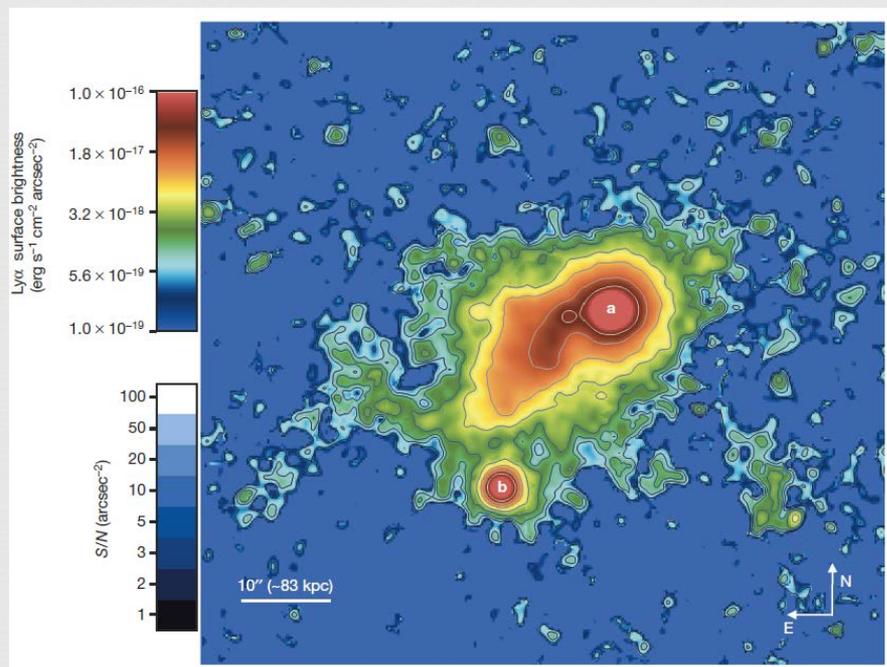


Cantalupo+14

Keck/LRIS




 Ly α scattering filament of “Cosmic Web” around a QSO at $z=2.3$

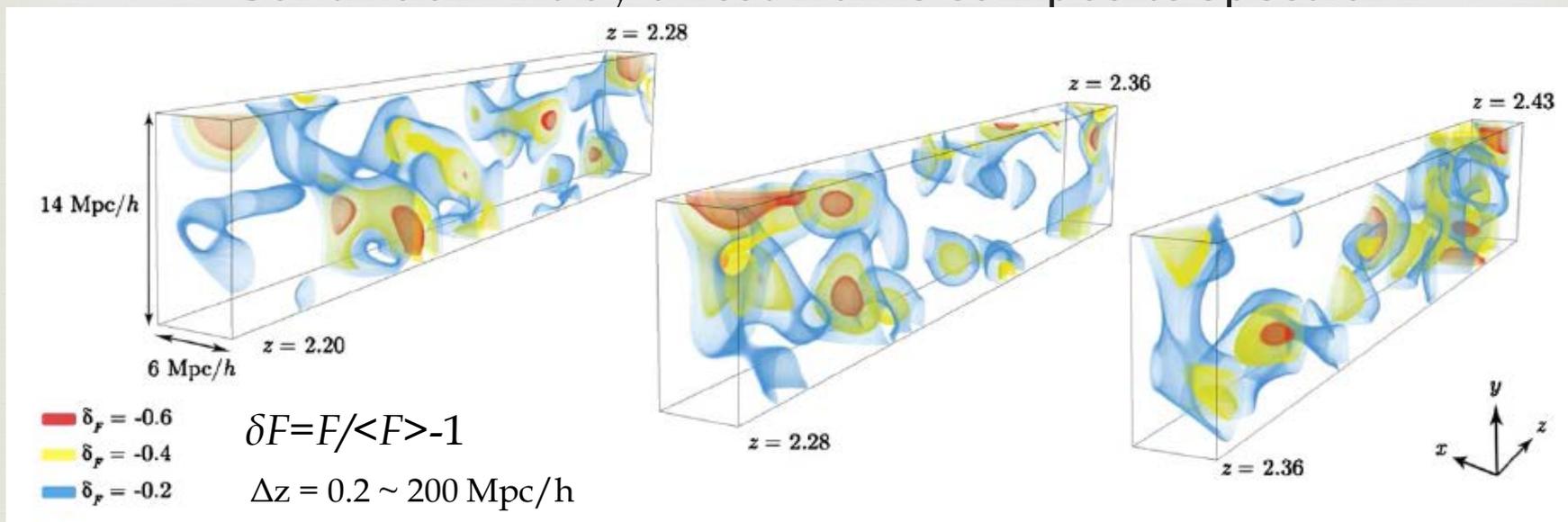


Lee+14

Keck/LRIS



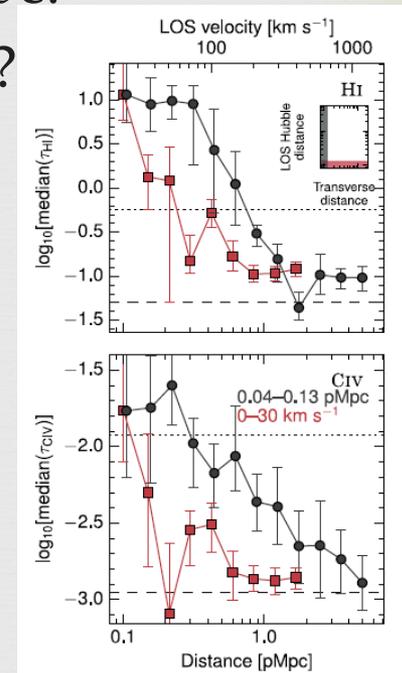
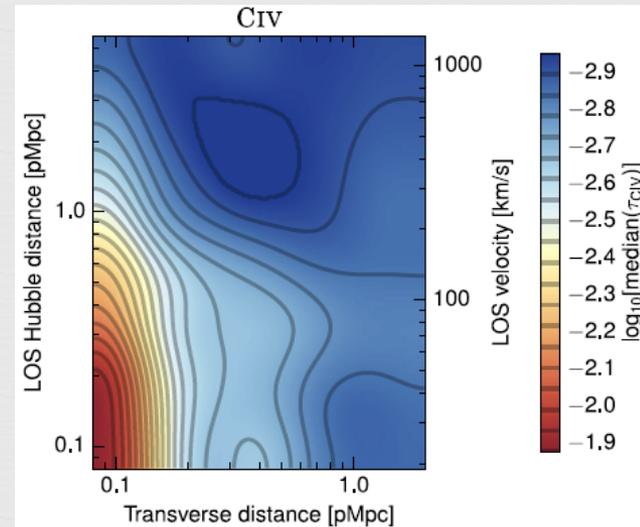
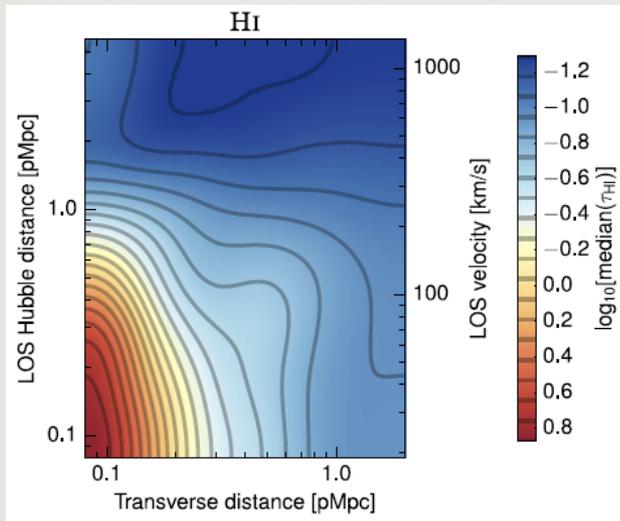
- ☞ IGM HI absorption through galaxies' spectra
 - ☞ 24 galaxies with $g < 24.9$ at $z \sim 2.5$
 - ☞ Continuum fit by a rest-frame composite spectrum



Turner+14

Keck/HIRES, LRIS, NIRSPEC, MOSFIRE

- QSO spectra piercing $z \sim 2.4$ foreground galaxies' CGM
- CIV (and HI) absorption excess up to 2 pMpc!
- Outflow reaching >10 times of virial radius?

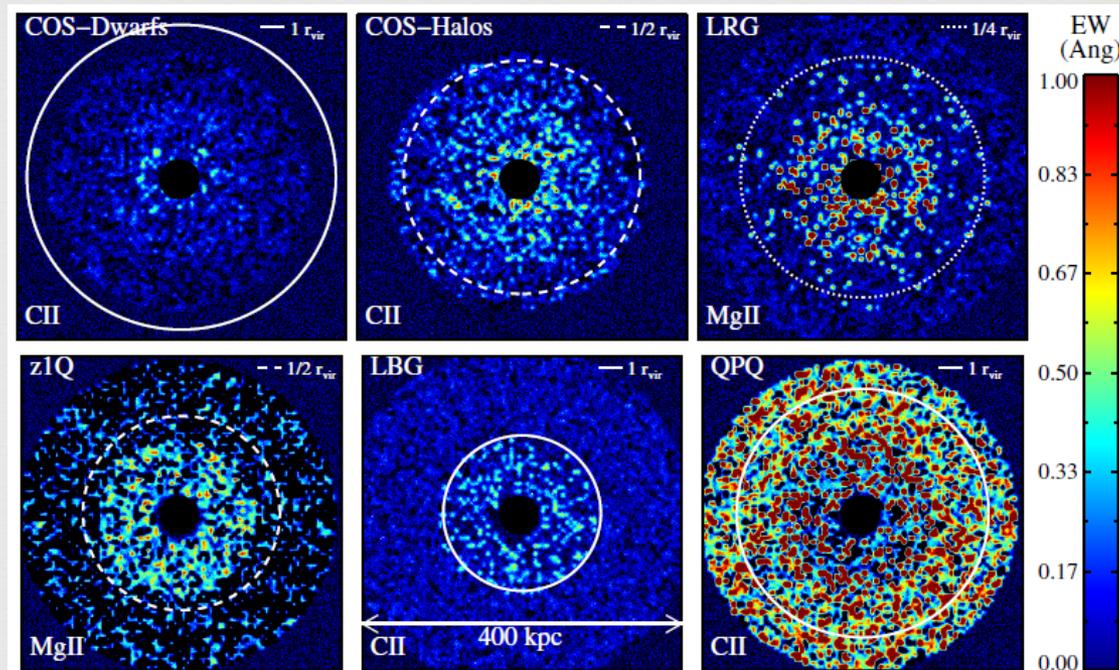
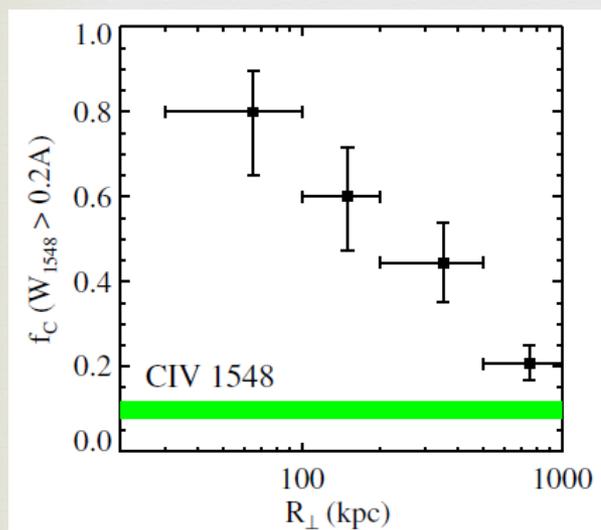


Prochaska+14

Keck/LRIS



 QSO CGM: higher excess of HI, CII, CIV than LBG CGM



Visualization (not observation)

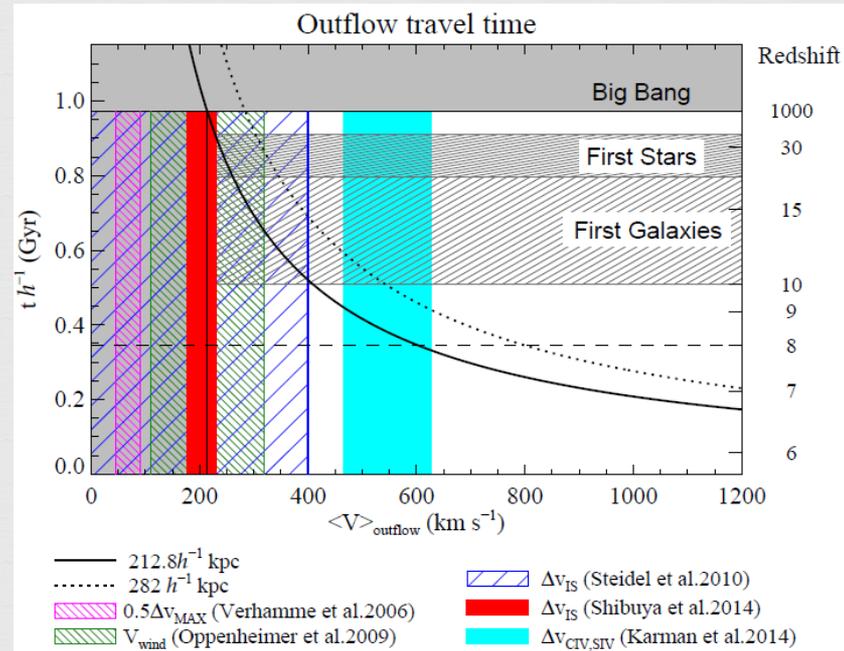
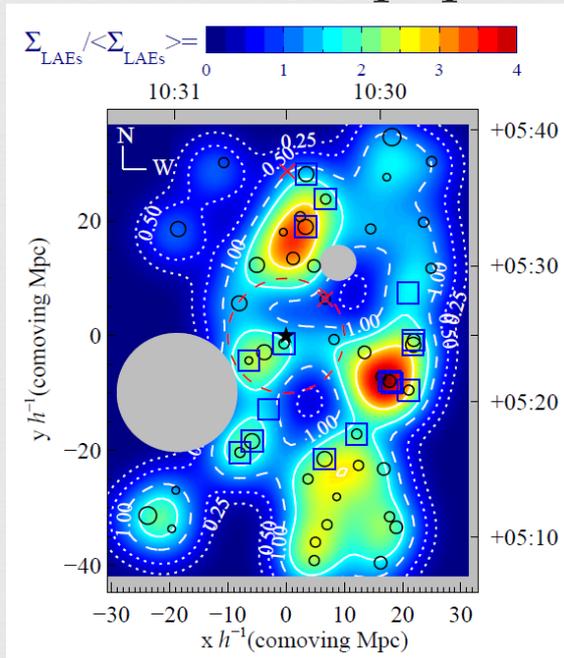
Diaz+14, 15

Subaru/S-Cam
Keck/DEIMOS



Excess of LAEs around a CIV absorber at $z=5.7$

$\sim 200/h$ pkpc separation: early enrichment in the IGM?

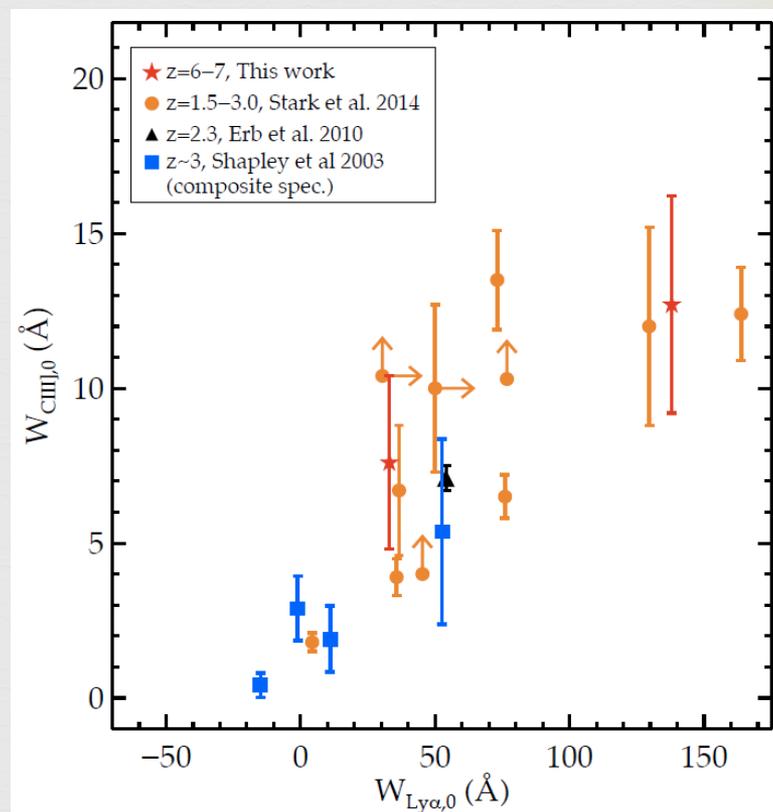


Stark+14,15

Keck/LRIS, MOSFIRE
VLT/FORS2, X-Shooter



- ❧ CIII] 1909 line detections from $M_{\text{star}} \sim 6e7 M_{\text{sun}}$ galaxies at $z \sim 2$
- ❧ OIII] 1661/1666, SiIII] 1883/1892, CIV 1549 are also detected.
- ❧ $\log U \sim -2$, $Z \sim 0.1 Z_{\text{sun}}$, sub-solar C/O ratio
- ❧ 2 high- z CIII] detections at $z=6.0$ and 7.2



遠方銀河に関する ALMAの成果



[CII]輝線 (Ota+14, Ono+14)
ダスト連続光 (Berger+14)
Cy2 preliminary result

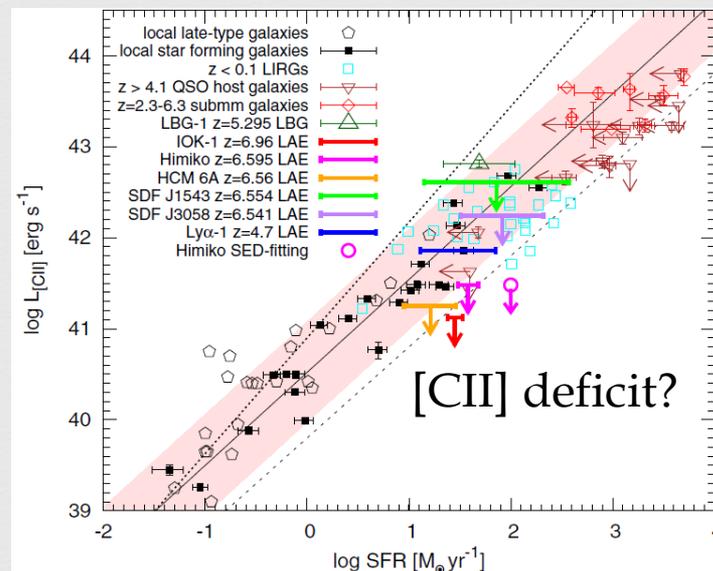
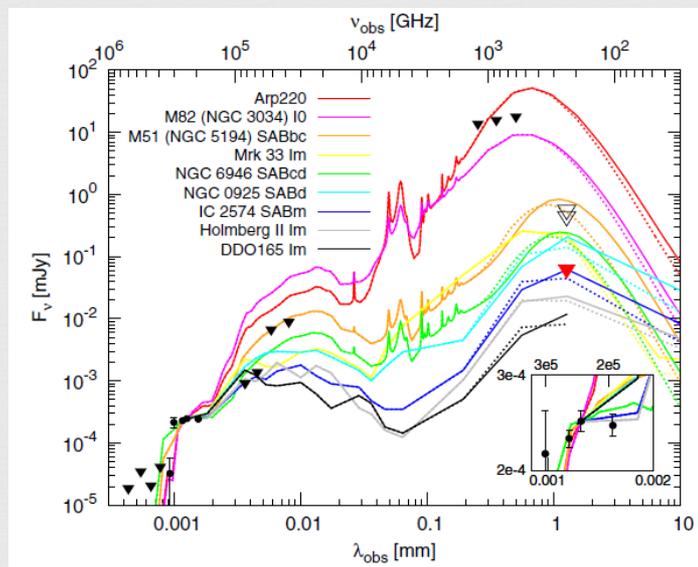
Ota+14

ALMA



 IOK-1 ($z=6.96$): [CII]158 and dust continuum were not detected with ALMA.

 $M_{\text{dust}} < 6.4e7 M_{\text{sun}}$, dust-obscured SF $< 29\%$

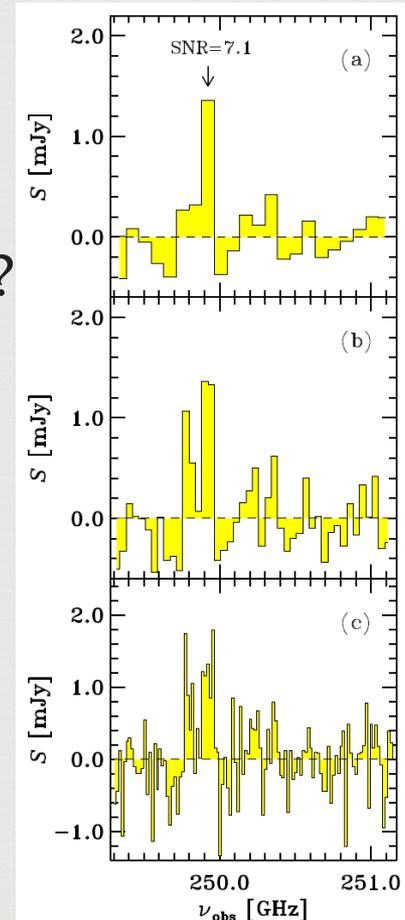
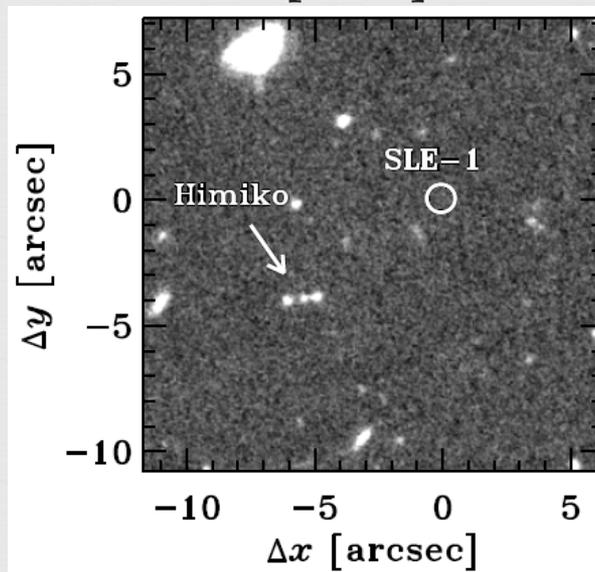
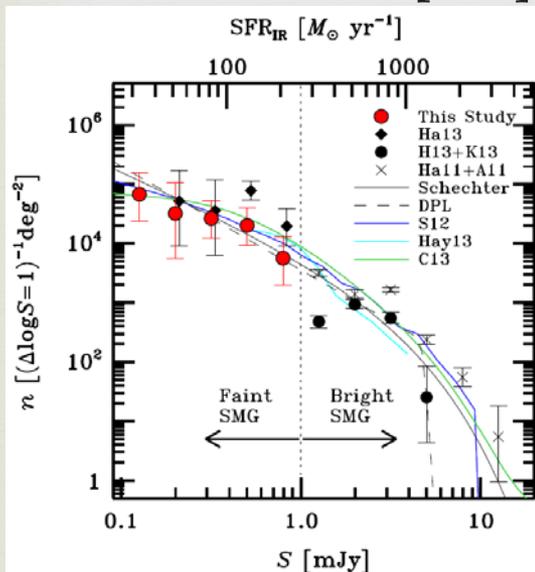


Ono+14



ALMA

- ∞ Faint sub-mm number count update.
- ∞ Single 1.2 mm emission line object
- ∞ $z=6.6$ [CII] emitter or $z=13$ [OIII] emitter?

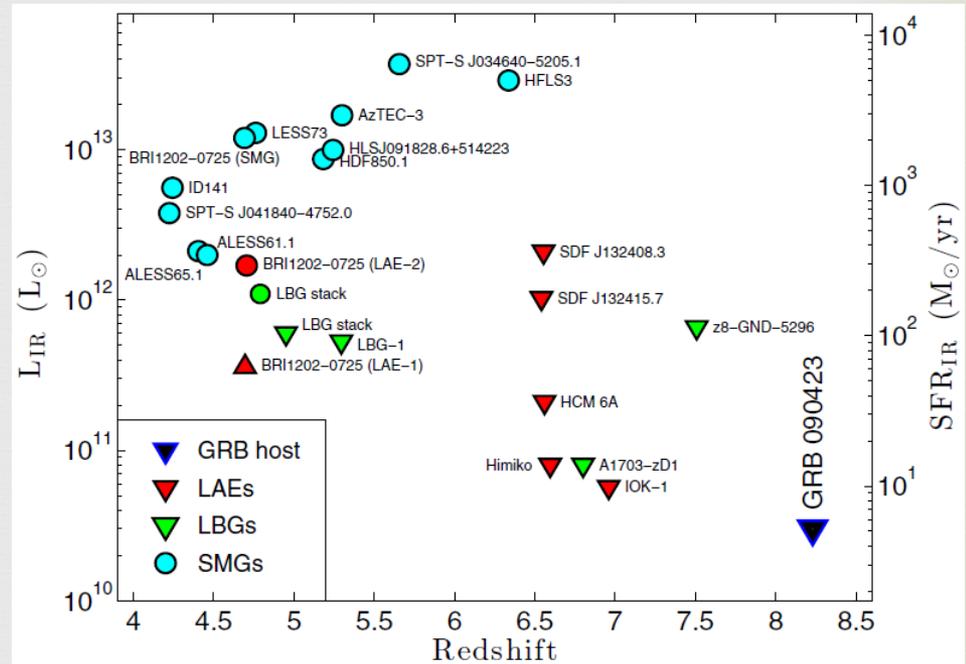
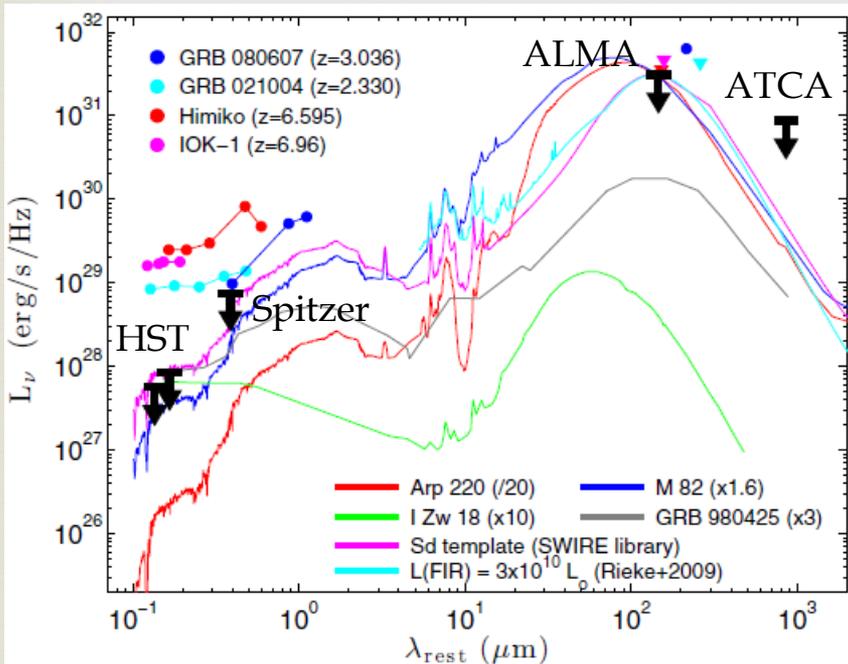


Berger+14

ALMA



GRB090423 at $z=8.23$ host galaxy was not detected with ALMA 1.5 mm and Spitzer 3.6 micron.



Cy2 preliminary result

ALMA



☞ [CII] deficit in high-z LAEs

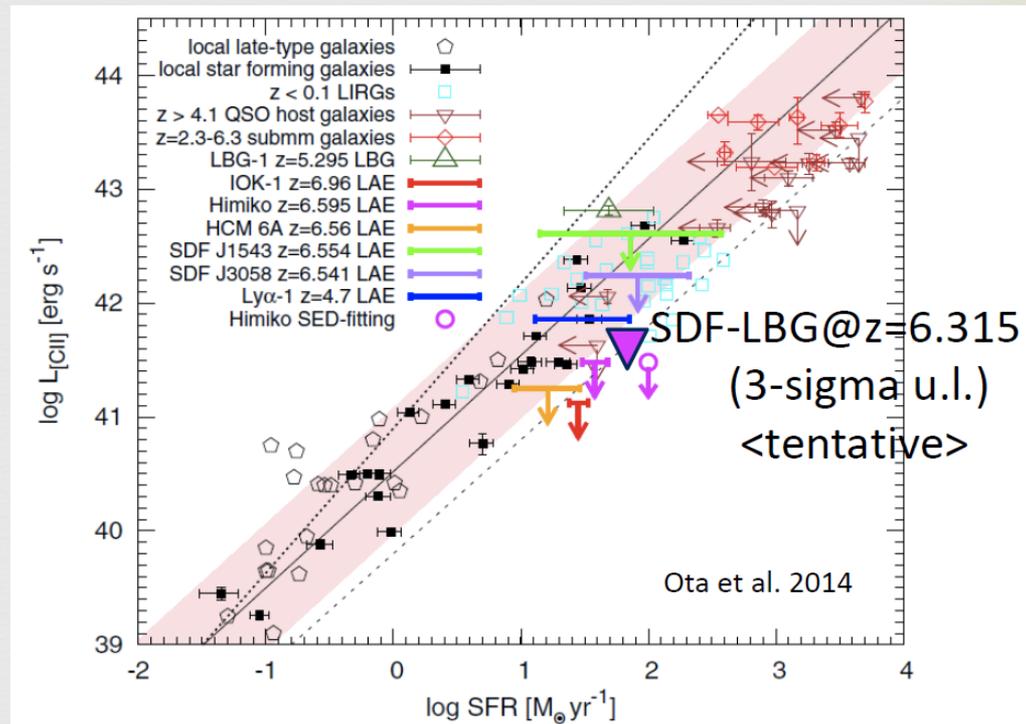
☞ No C+ but C2+ due to strong radiation?

☞ [OIII]88/[CII]158 ratio is interesting.

☞ Cy2 proposal for [OIII]88 and [CII]158

☞ SDF-LBG at z=6.3

☞ SXDF-LAE at z=7.2



将来展望



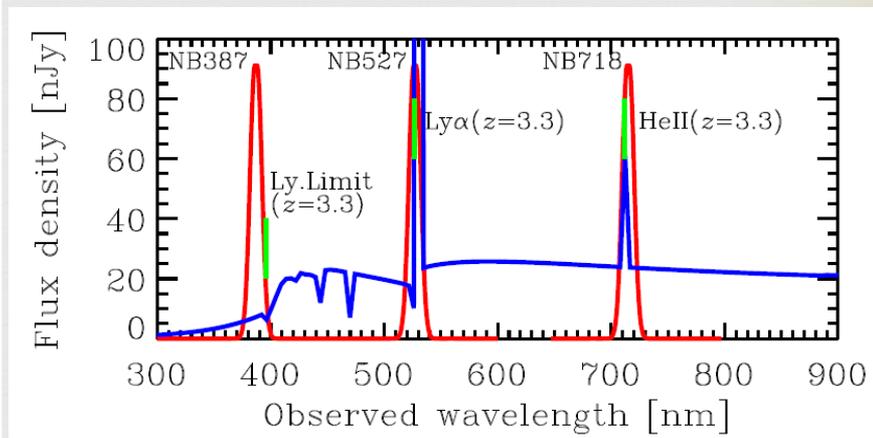
Subaru/HSC NB探査
Subaru/PFS HI 3D mapping
2020年代のUV光度関数

Subaru/HSC NB探査



- ☞ SSP UD相当のNBキャンペーン→S16Aから？
 - ☞ $z=2\sim7$ LAE光度関数、クラスタリング、 $\text{Ly}\alpha$ ハロー
 - ☞ $z=3.3, 4.9$ 電離光子探査
 - ☞ $z=4.9$ CIV, HeII輝線探査、AGN探査
 - ☞ $z=6.6$ 電離度測定、電離度空間分布マッピング

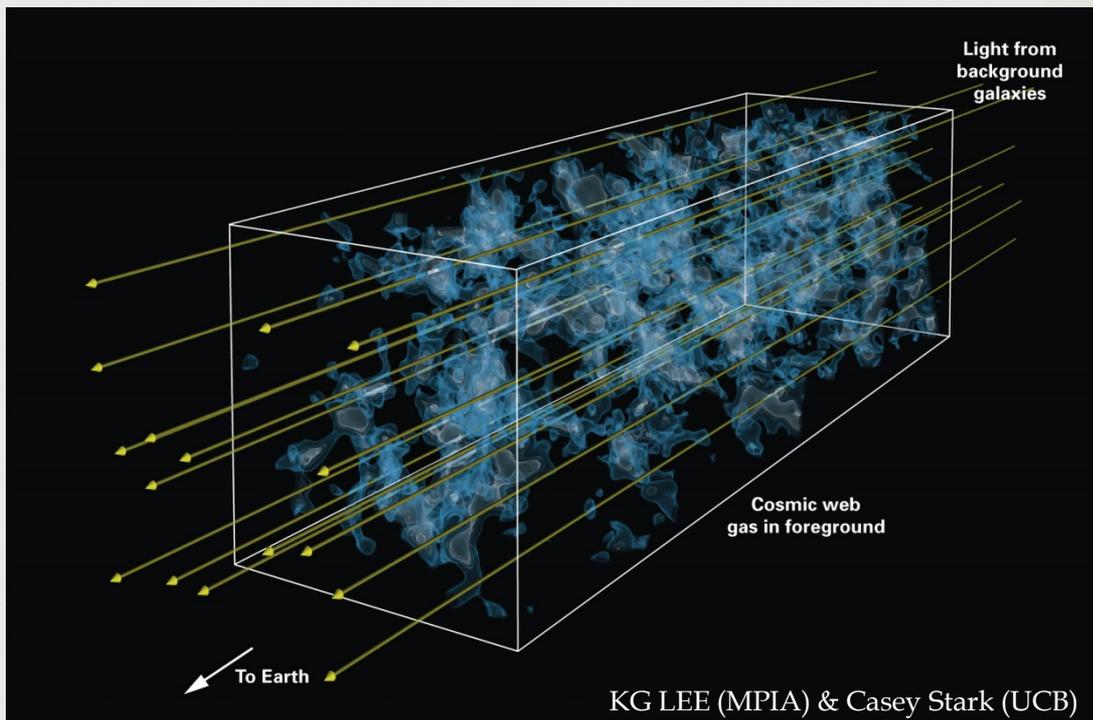
	HSC SSP	$z(900)$	$z(\text{Ly}\alpha)$	$z(\text{CIV})$	$z(\text{HeII})$
NB387	Deep	3.3	2.2		
NB527	—	4.9	3.3		2.2
NB718	—		4.9		3.3
NB816	Deep/UD		5.7		
NB921	Deep/UD		6.6	4.9	
IB945	—		6.8		
NB973	—		7.0		4.9
NB101	UD		7.3		



Subaru/PFS HI 3D mapping



- Tomography by galaxy absorption line systems
- Galaxy-HI cross-correlation
- Metal lines also?
 - Feedback etc.



KG LEE (MPIA) & Casey Stark (UCB)

2020年代のUV光度関数



- ❧ 「初代銀河」光度関数の測定
- ❧ JWSTは視野が狭いため厳しいか？
- ❧ 広視野が必須→WISH, WFIRST
- ❧ $z \sim 14$ LBG選択は波長
2ミクロン以上が要求される

石垣 (2015修論)

