南極THz望遠鏡による遠方銀河の輝線探査

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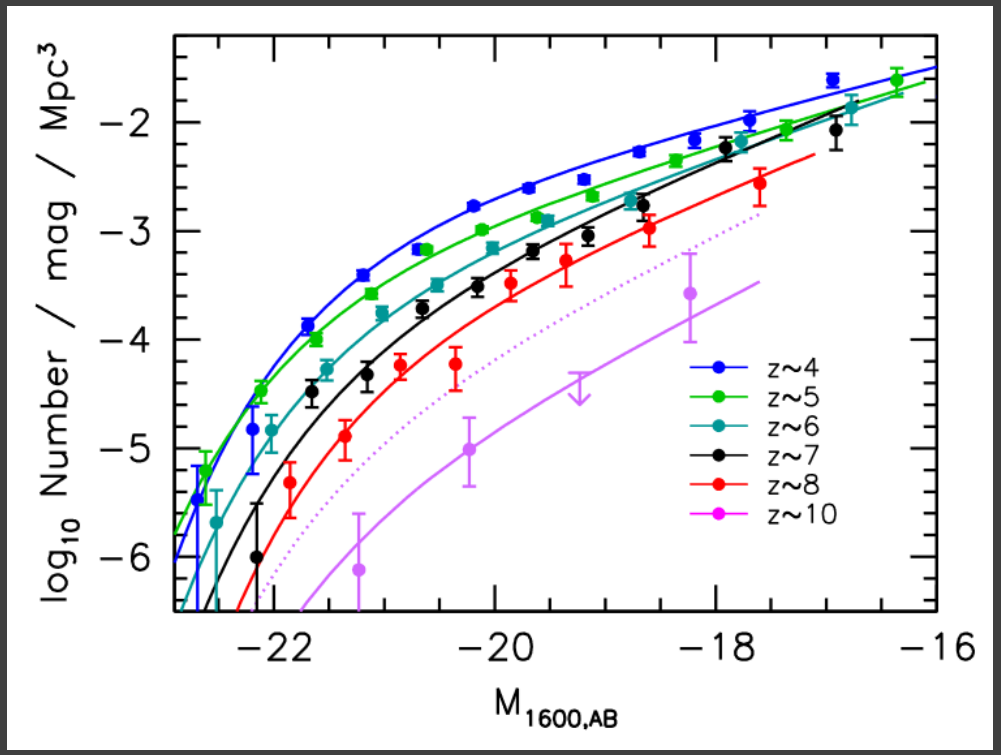
話の内容

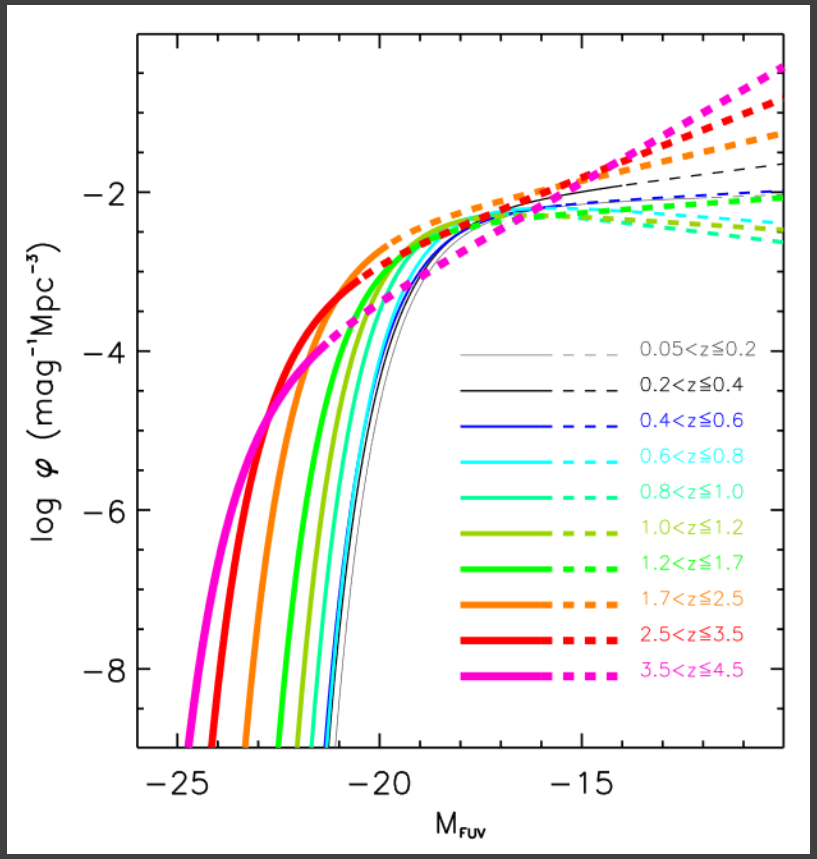
- 遠方銀河観測の現状
- 赤方偏移z=7.2の[OIII]88輝線検出
- [OIII]52/88輝線予想光度関数
- 議論

紫外線光度関数

Bouwens et al. (2015) with HST/WFC3

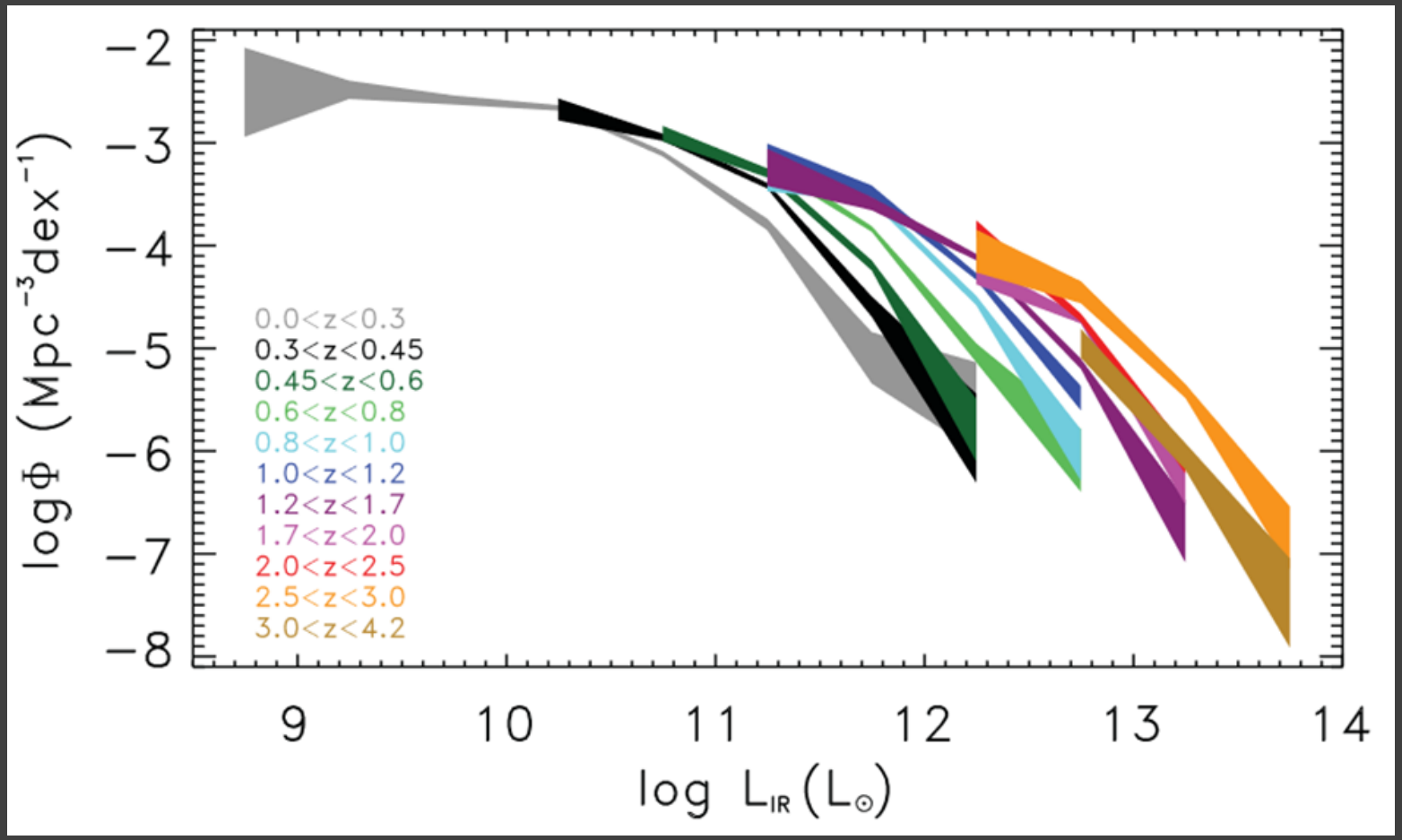


Cucciati et al. (2013) with VVDS



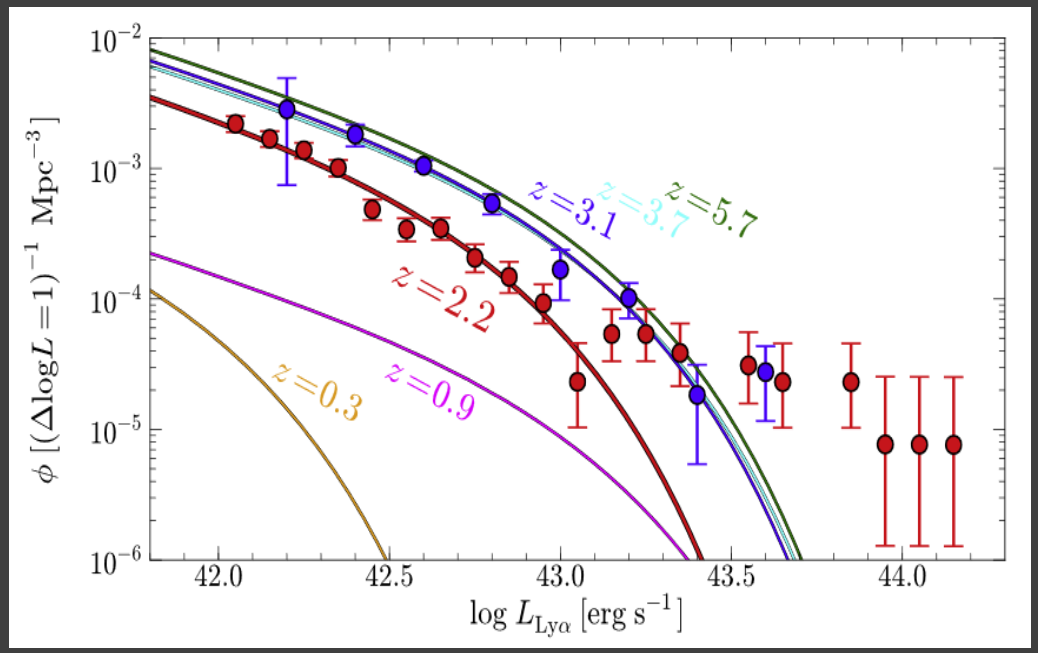
赤外線光度関数

Gruppioni et al. (2013) with Herschel

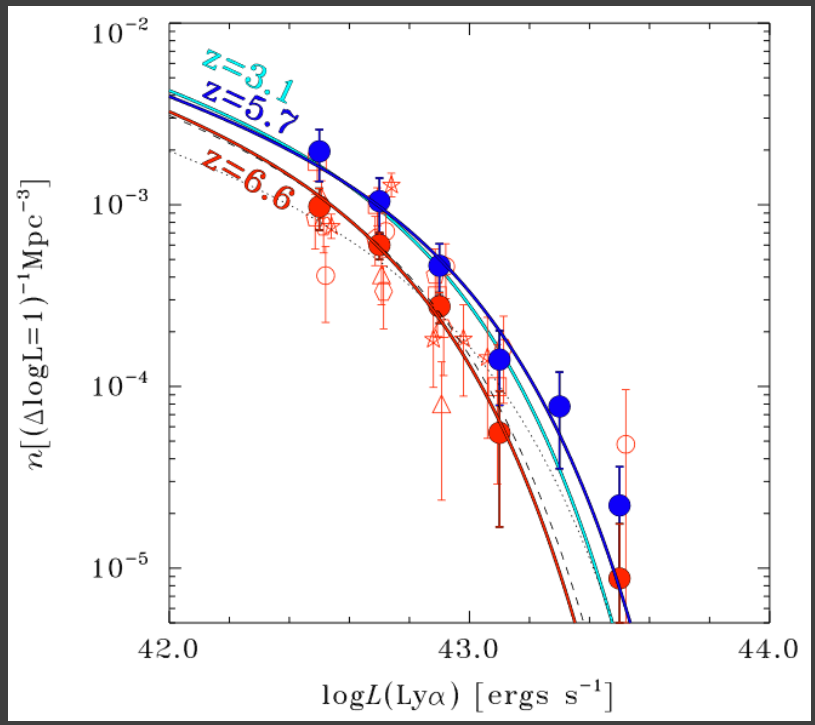


Lyα光度関数

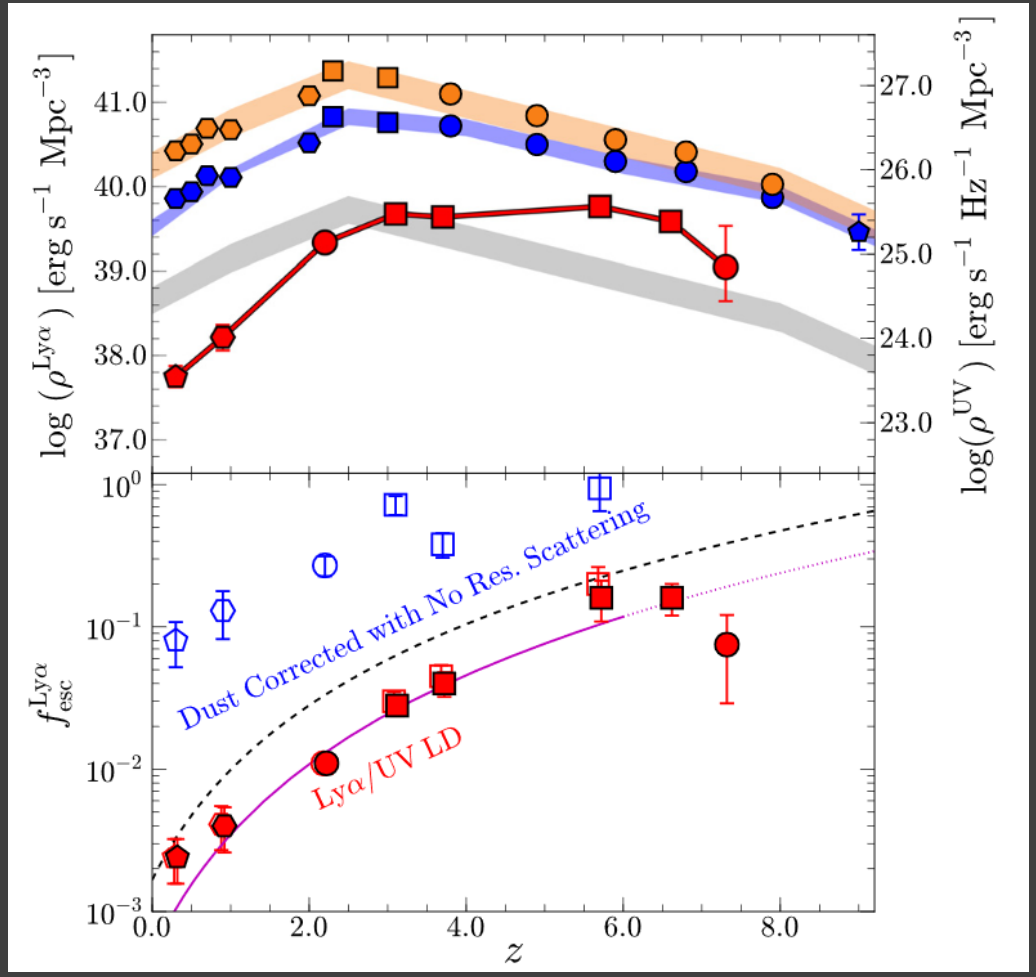
Konno et al. (2016)



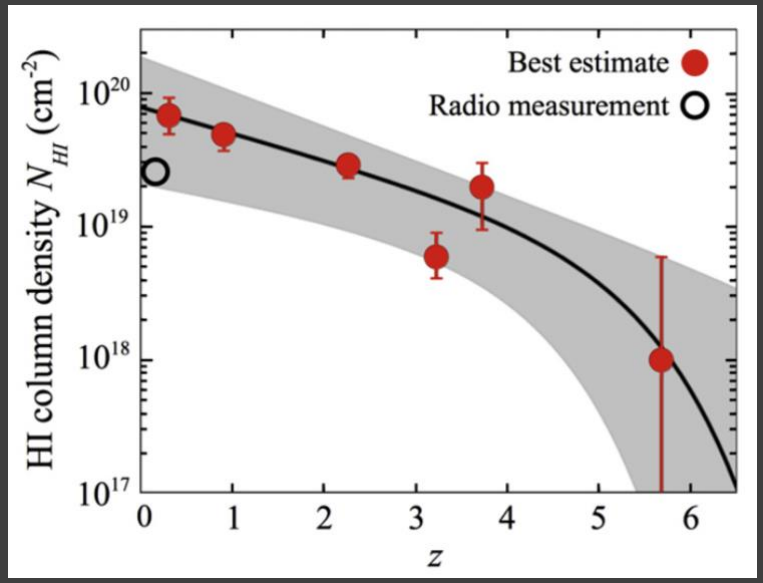
Ouchi et al. (2010)



Lyα光度密度vs紫外線光度密度

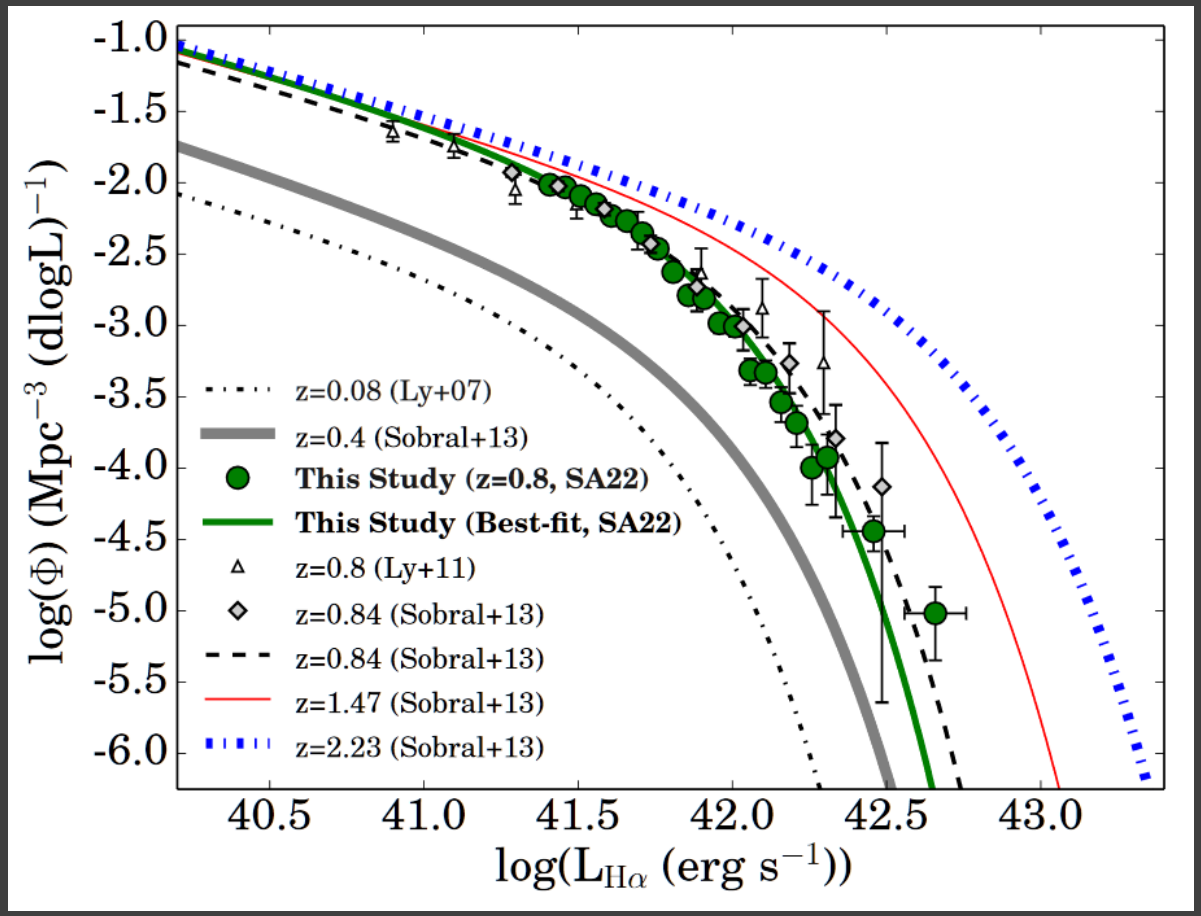


Konno et al. (2016)



Hα光度関数

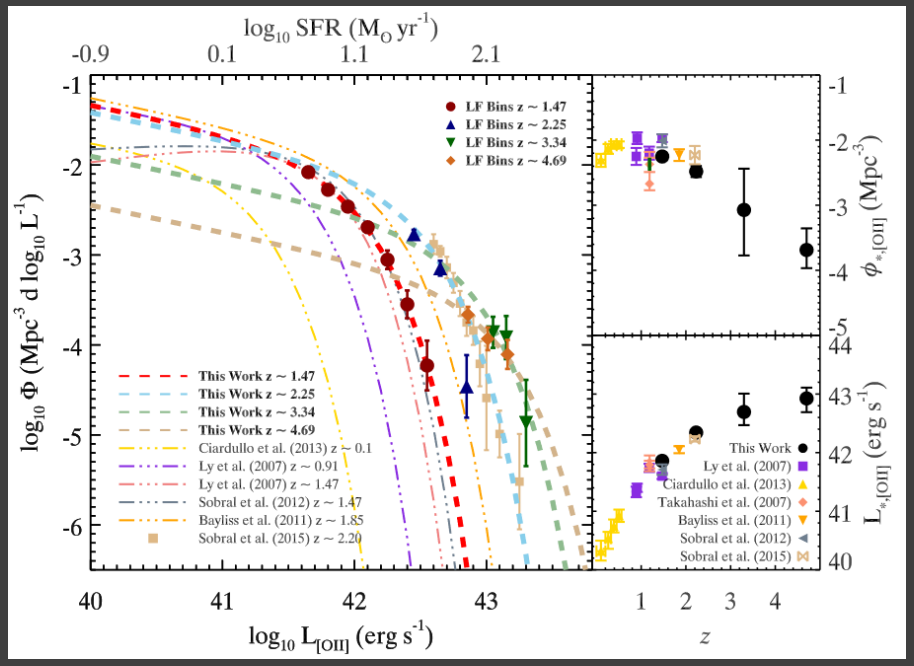
Sobral et al. (2015)

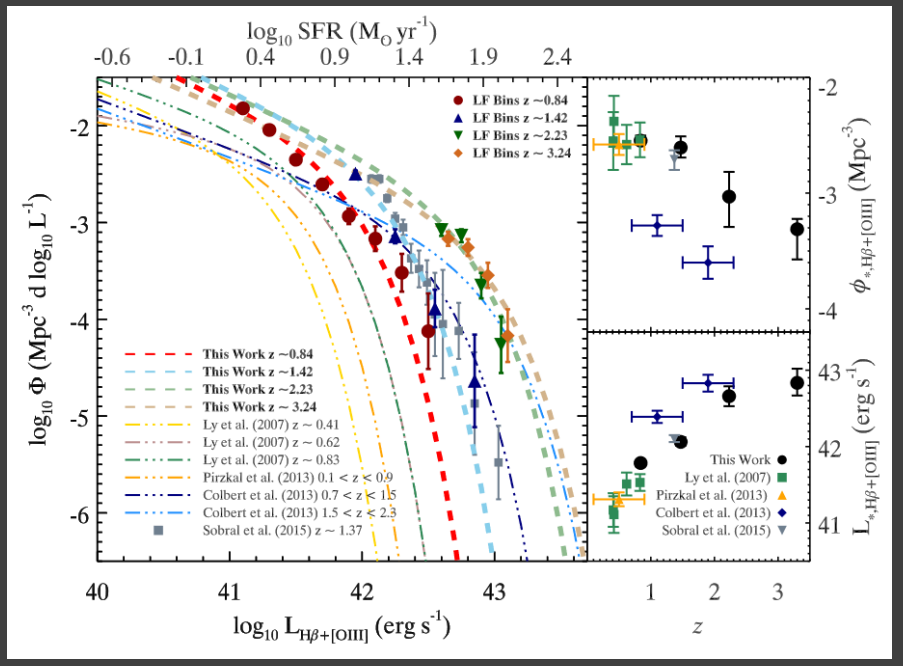


⇒2.8<z<6.6 with JWST

[OII]3727, [OIII]5007光度関数

Khostovan et al. (2017)

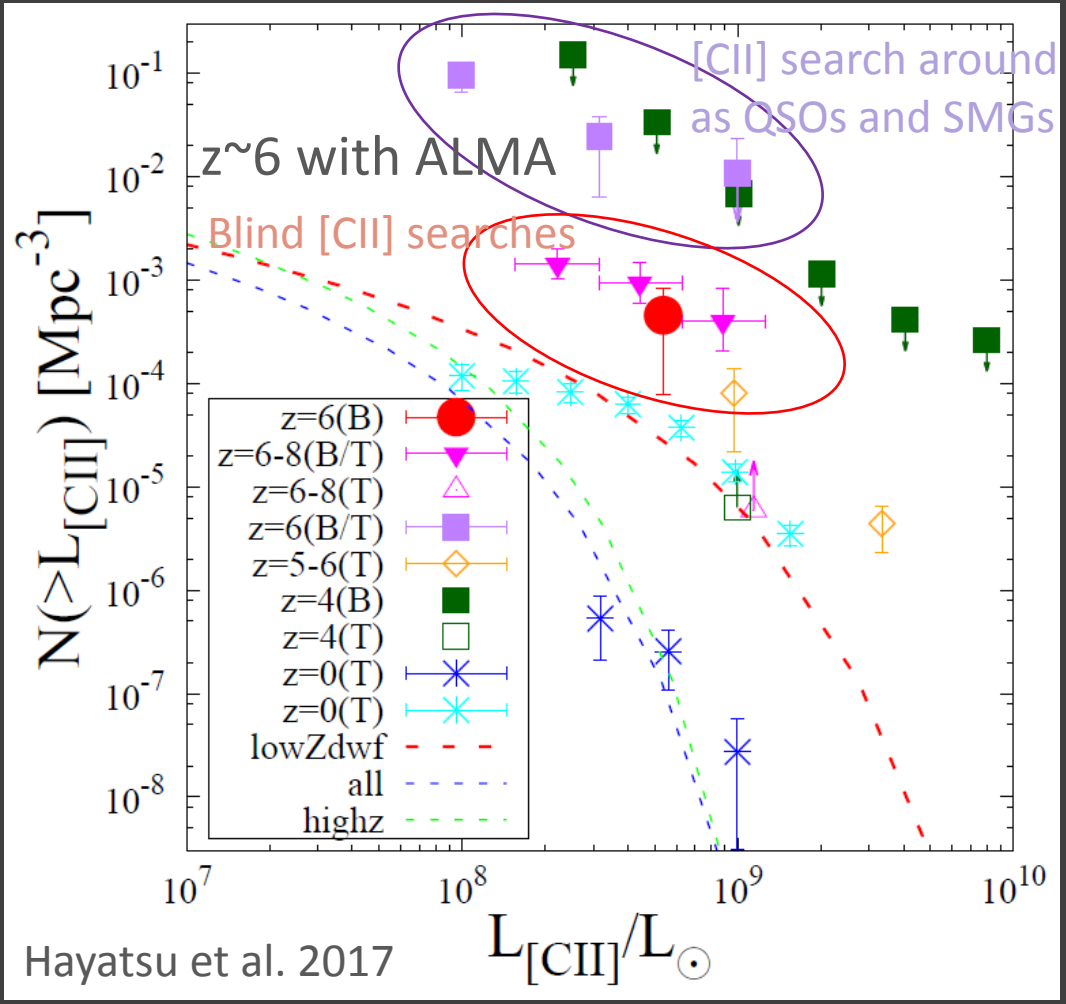




⇒5.7<z<12 with JWST

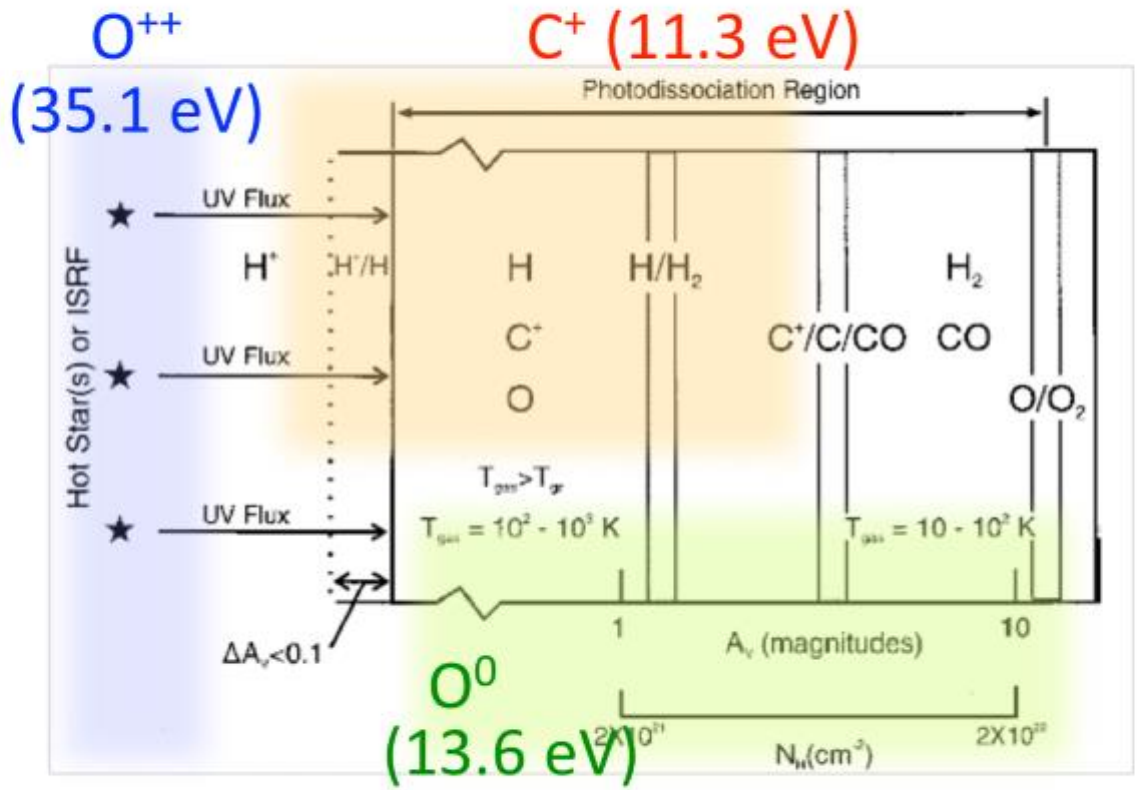
⇒4.0<z<9.0 with JWST

[CII]158光度関数


[CII] search around massive halos such as QSOs and SMGs by Miller+16
z~6 with ALMA
Blind [CII] searches
z=6(B)
z=6-8(B/T)
z=6-8(T)
z=6(B/T)
z=5-6(T)
z=4(B)
z=4(T)
z=0(T)
z=0(T)
lowZdwf
all
highz
$N(>L_{[CII]})$ [Mpc^{-3}]
$L_{[CII]}/L_\odot$
Hayatsu et al. 2017

By Courtesy of Y. Tamura

Photodissociation region



Tielens & Hollenbach 2005, Phys. Rev.

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Viewgraph from ALMA WS 系外微細構造線勉強会 2014（田村）

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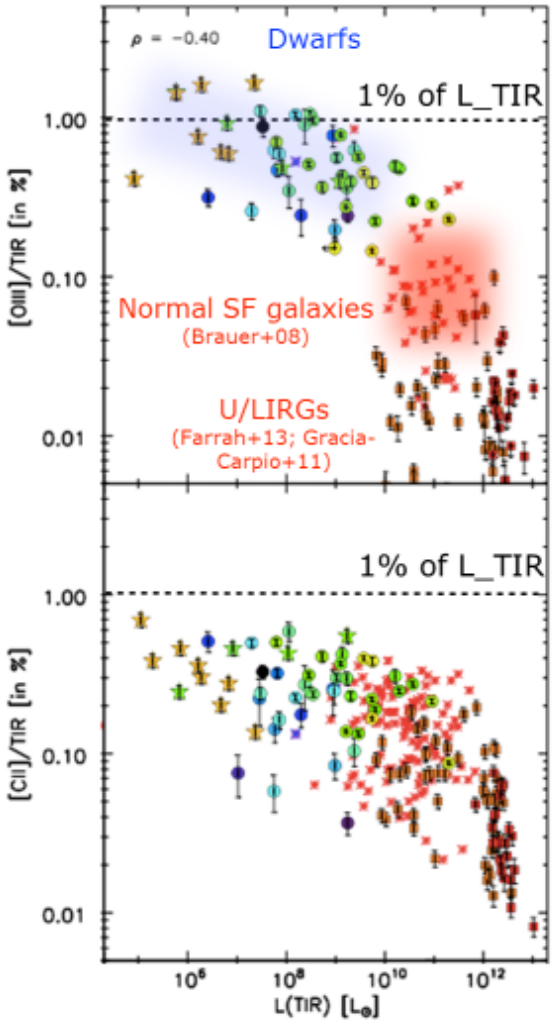
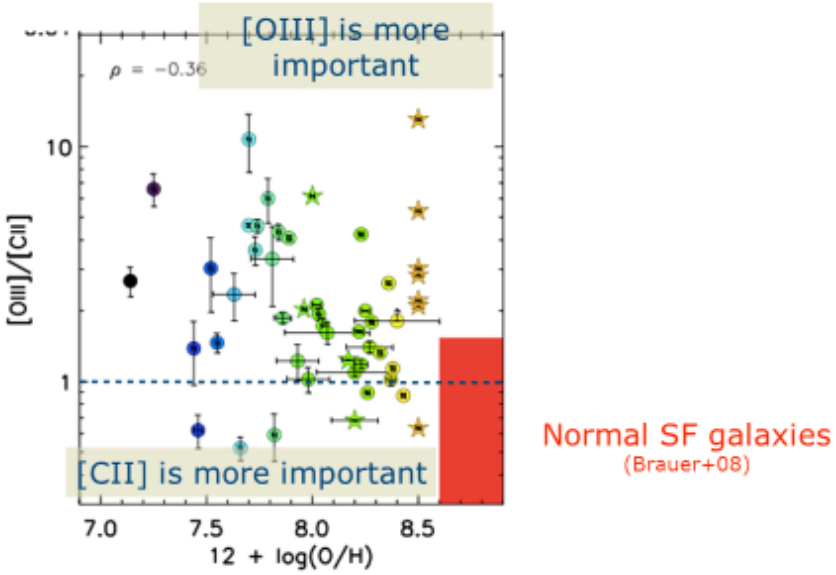
By Courtesy of Y. Tamura

Herschel Dwarf Galaxy Survey

Cormier+2015



- Local dwarfs (i.e. low metallicity SF galaxies) as low-z analogs of typical SF galaxies at high redshift.
- [OIII]88 is the brightest
  - L_[OIII]88 / L_[CII]158 > 1 (up to ~10).
- High ionization state and/or "truncated" PDRs (matter-bounded Stromgren sphere)?

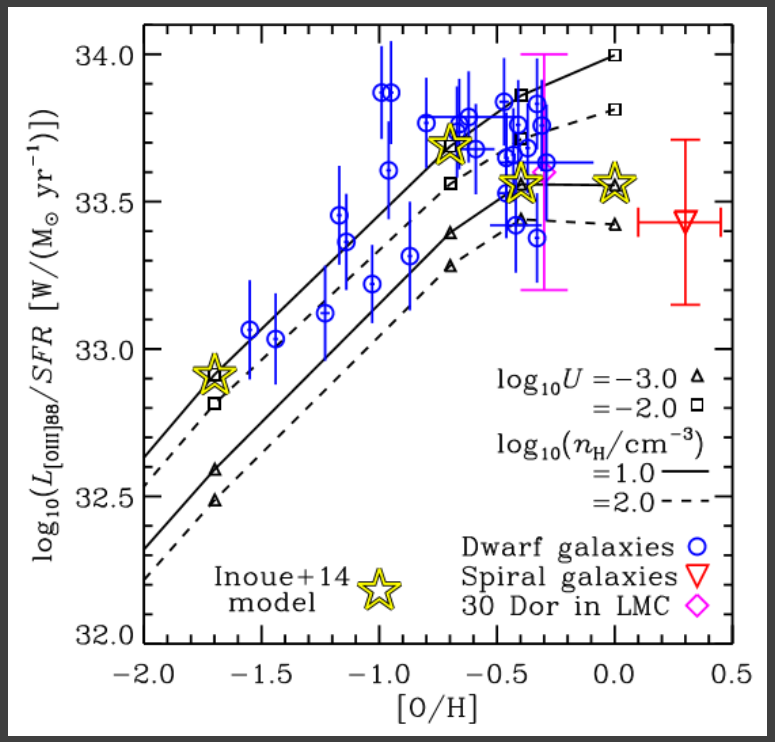


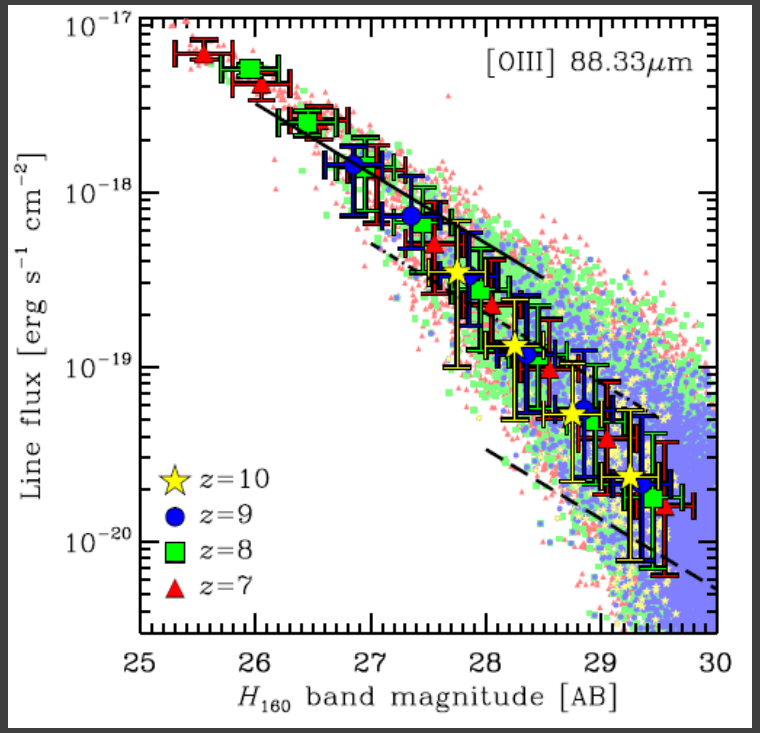
初期宇宙[OIII] 88μm輝線：予想

- Herschelによる近傍低金属量銀河の[OIII]88輝線観測結果にもとづく予想では、[OIII]88輝線はz>7でもALMAで検出可能→新しいプローブ

Inoue et al. (2014)

[OIII]放射率

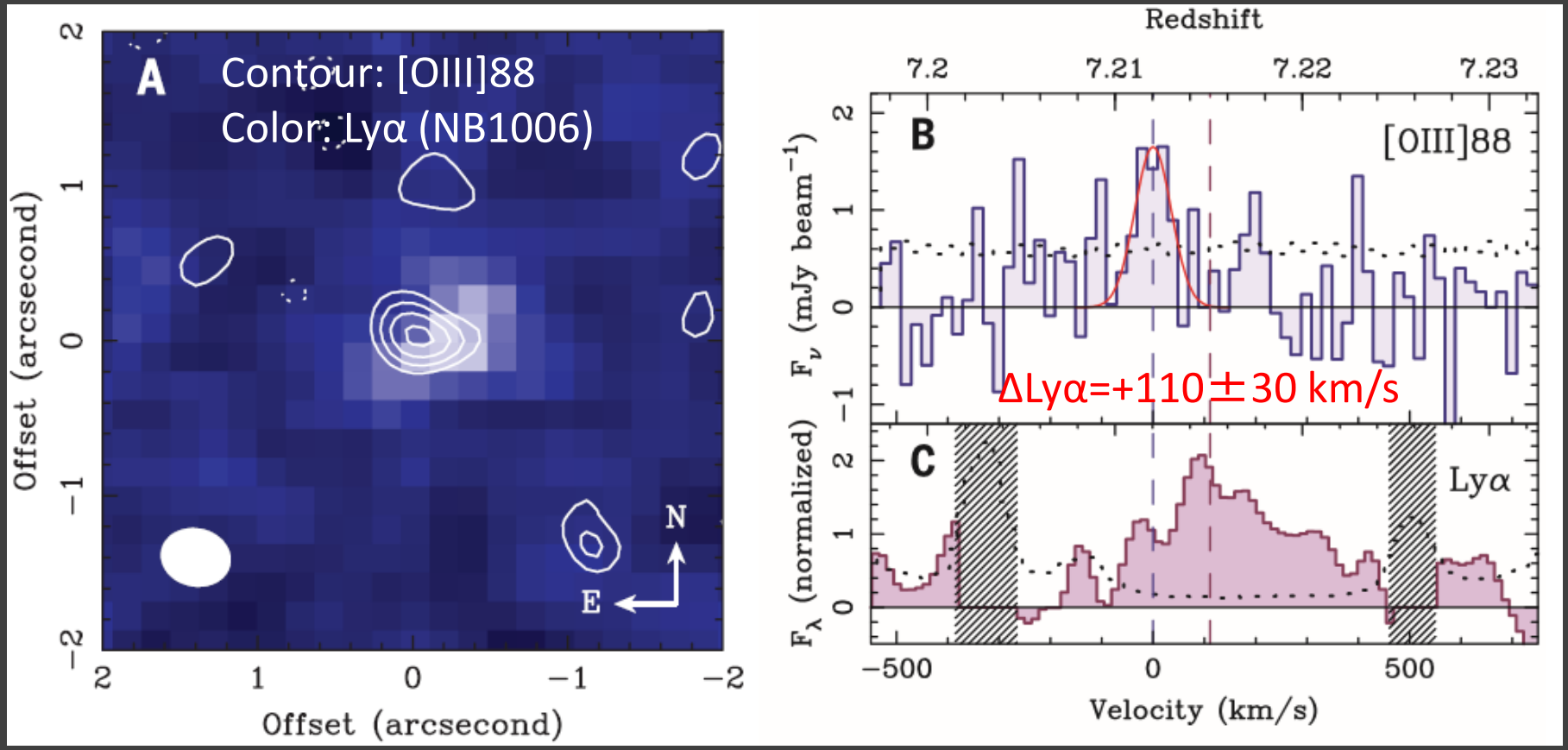




ALMA観測結果

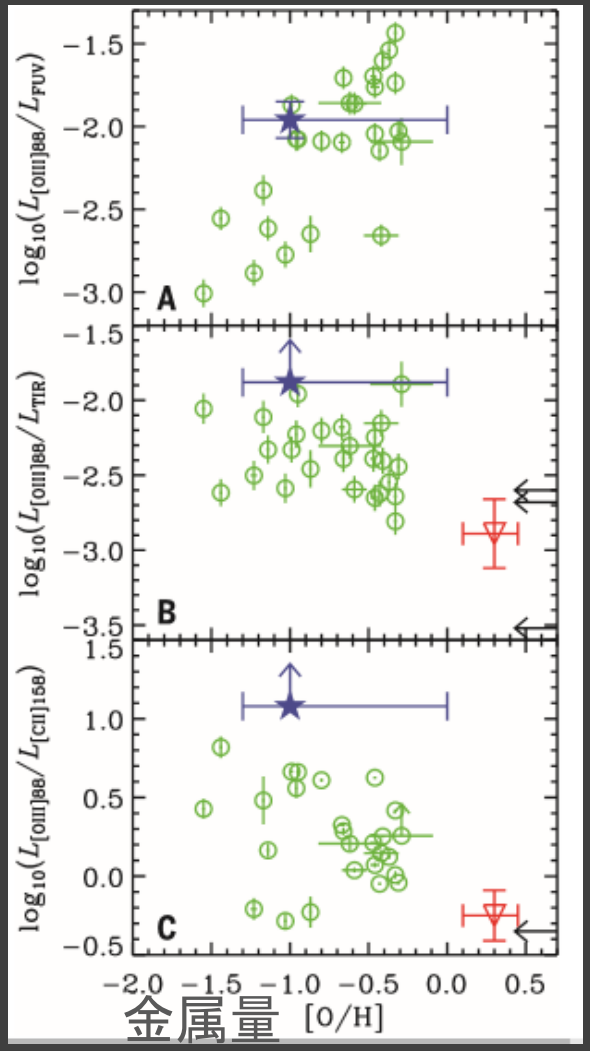
Inoue et al. 2016, Science

- [OIII] 88 μm輝線の検出(5.3σ).
  - z([OIII])=7.2120 → 最遠方酸素！

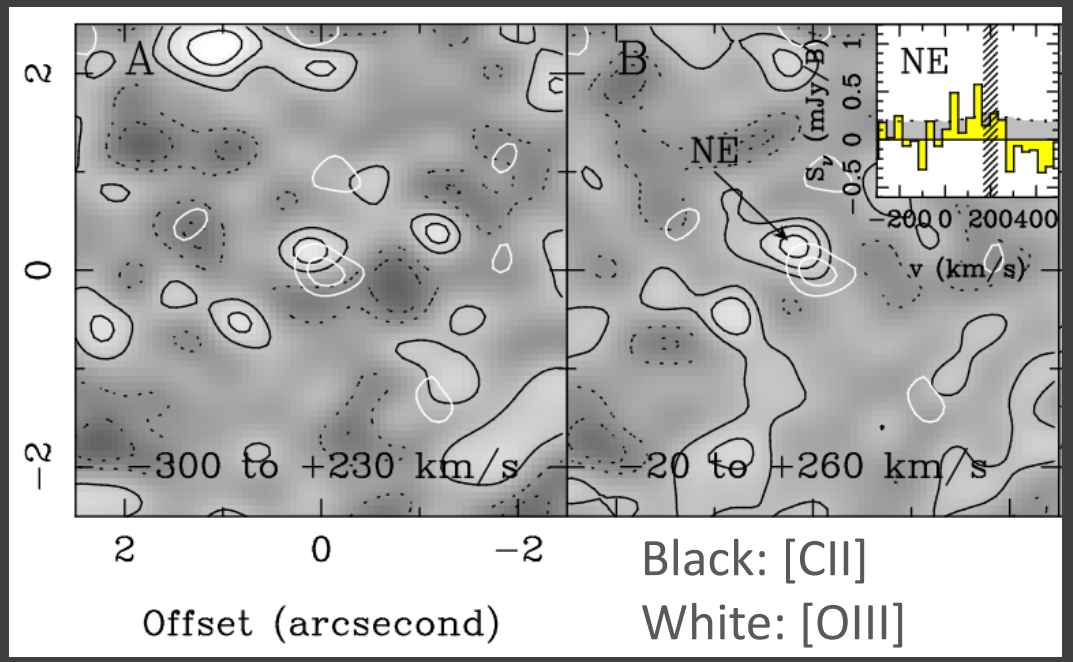


ALMA観測結果

Inoue et al. 2016, Science

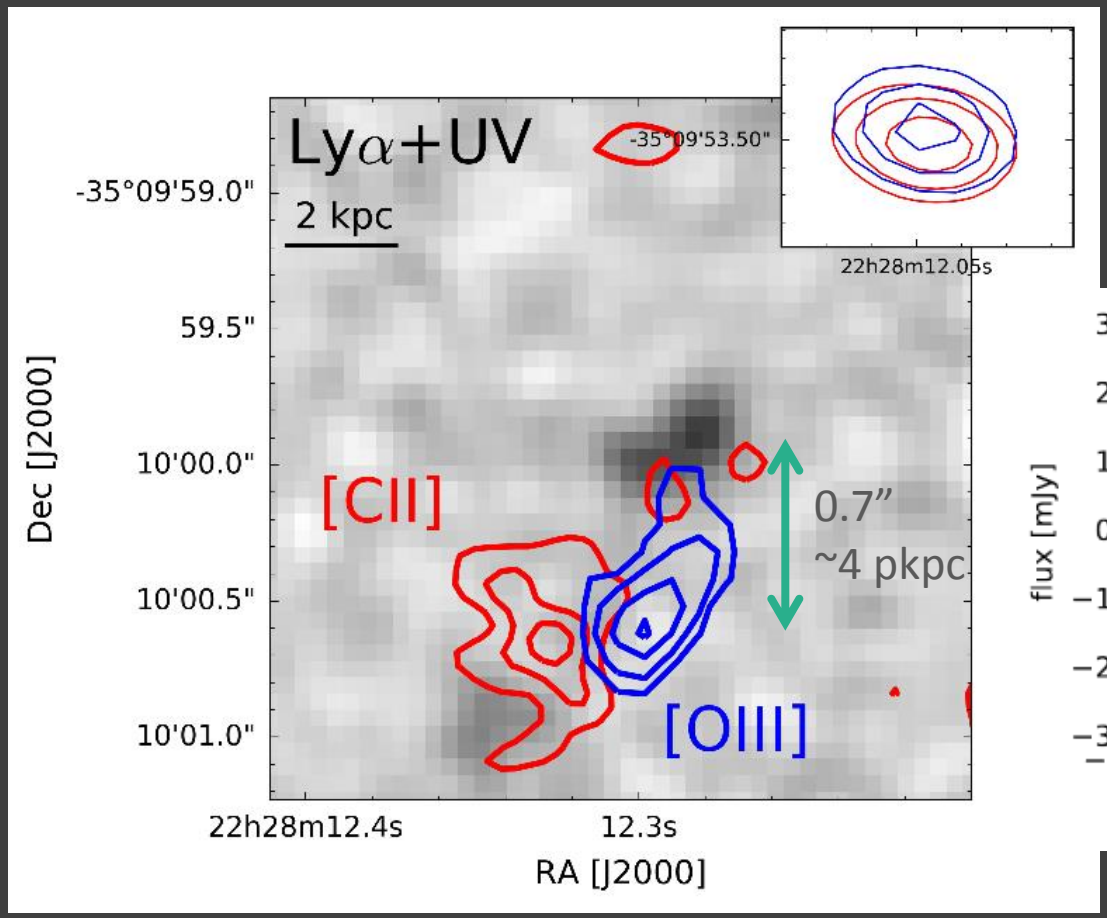


- [OIII]の位置で[CII]輝線は未検出
- ダスト連続光は未検出
  - Band 6 & 8

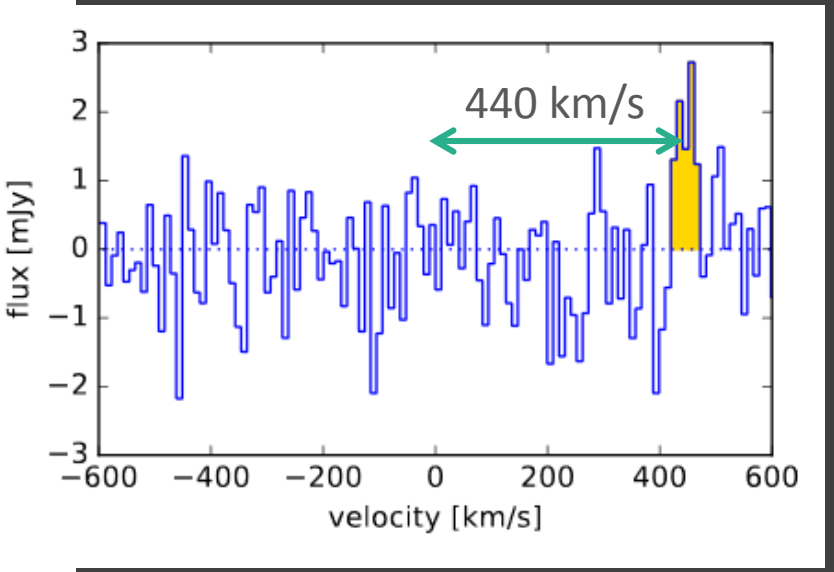


初期宇宙[OIII]88輝線検出2例目

Carniani et al. (2017) LBG/LAE z(Lyα)=7.109, z(OIII)=7.097

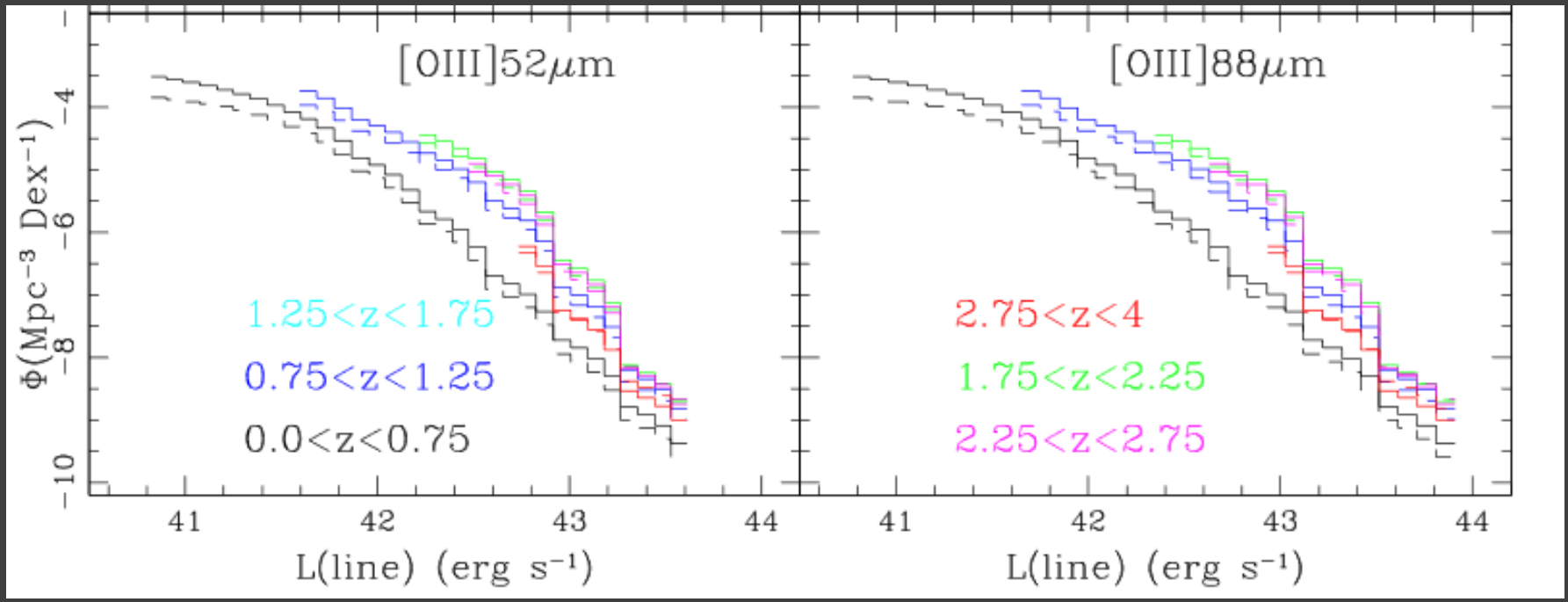


ALMA Bands 6 and 8
astrometric consistency

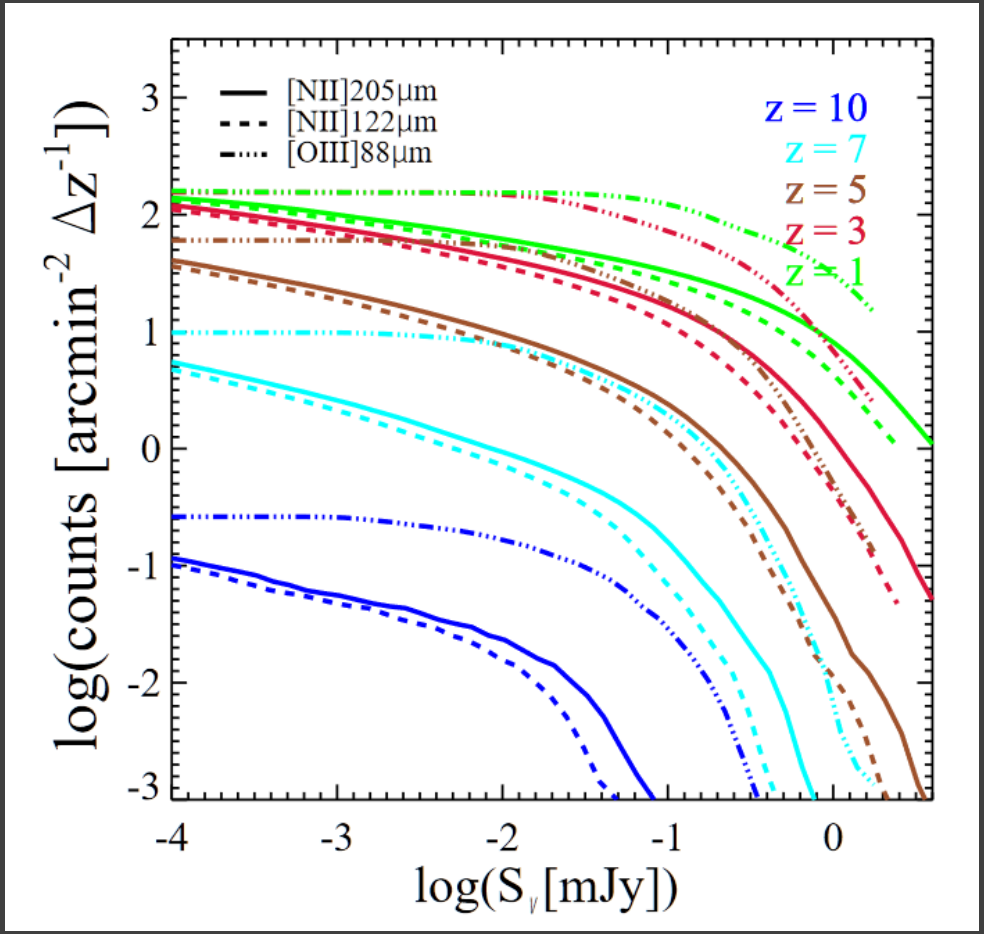


THz輝線予想光度関数

Empirical estimation based on IR luminosity functions (Spinoglio et al. 2012)



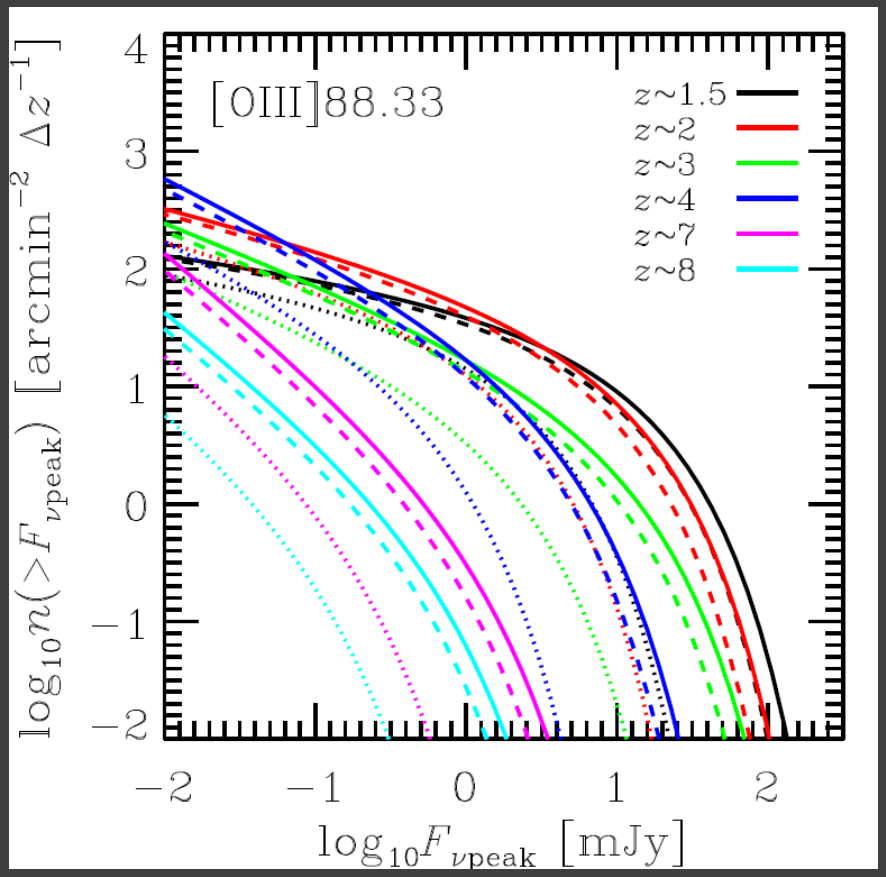
[OIII]88, [NII]122/205輝線予想光度関数

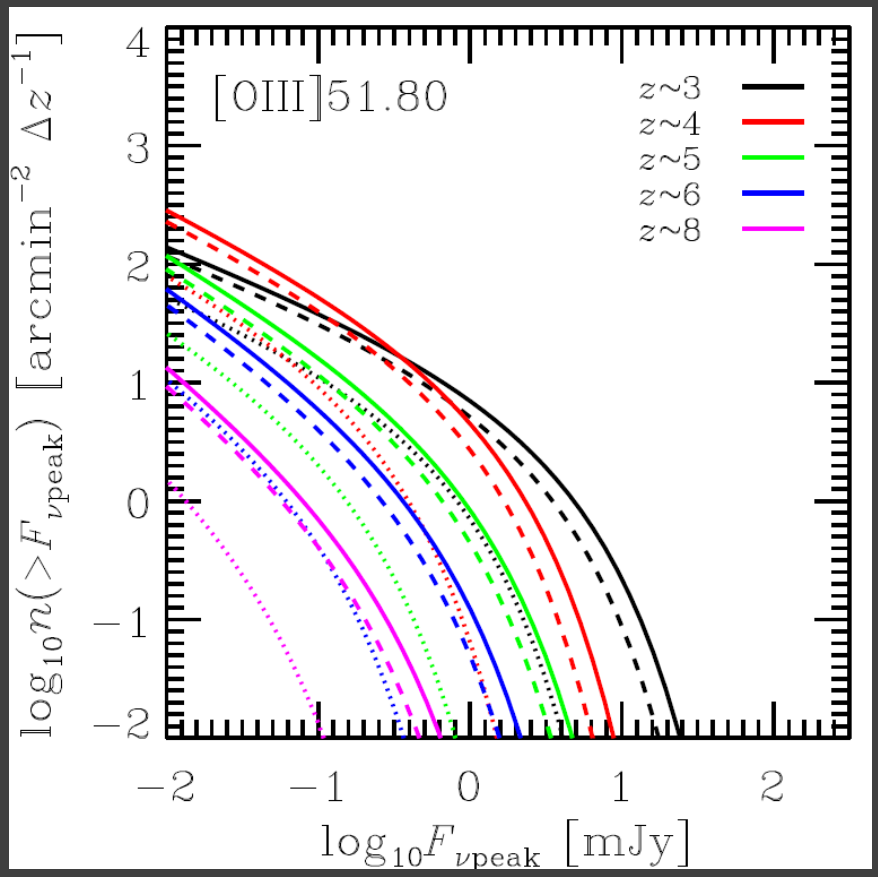


Orsi et al. (2014)
Semi-analytic model predictions using Mappings-III

輝線幅Δv=50 km/s

[OIII]52/88輝線予想光度関数

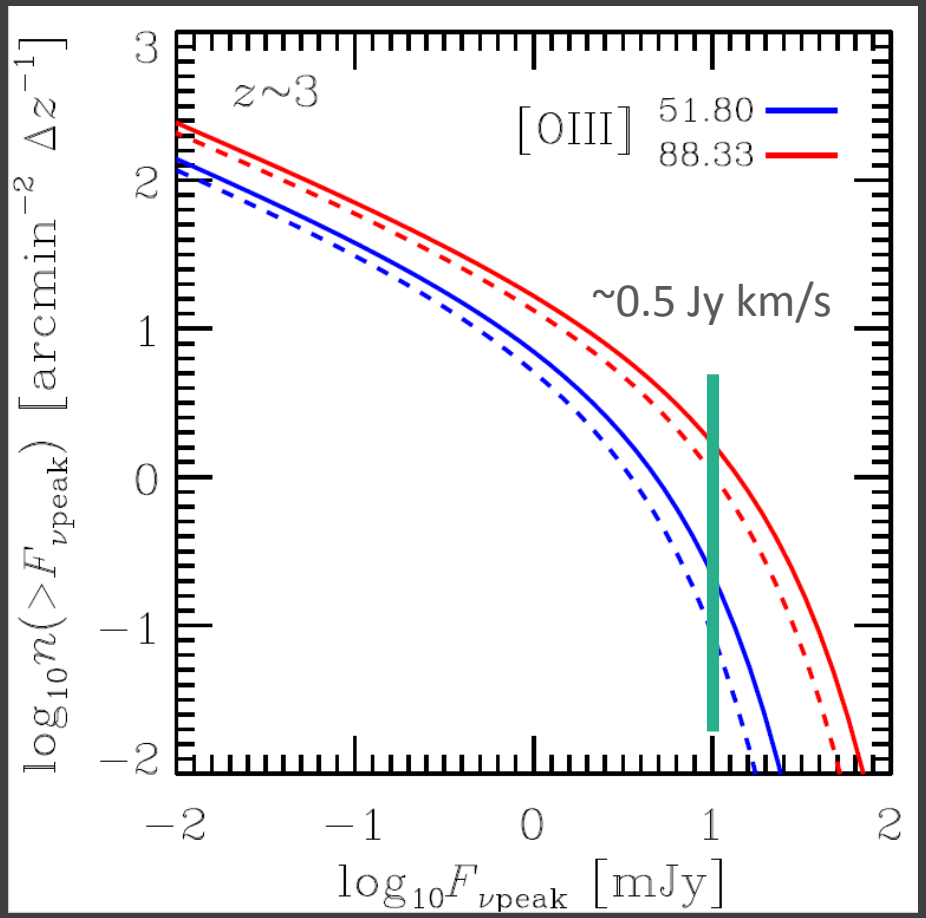




UV LF: Cucciati et al. (2013), Bouwens et al. (2015); UV dust correction (Burgarella et al. 2013)
Line emissivity (Inoue et al. 2014) 直線: Z=0.2Zsun, 破線: Z=Zsun, 点線: Z=0.02Zsun
輝線幅Δv=50 km/s

[OIII]52/88輝線予想光度関数

z~3

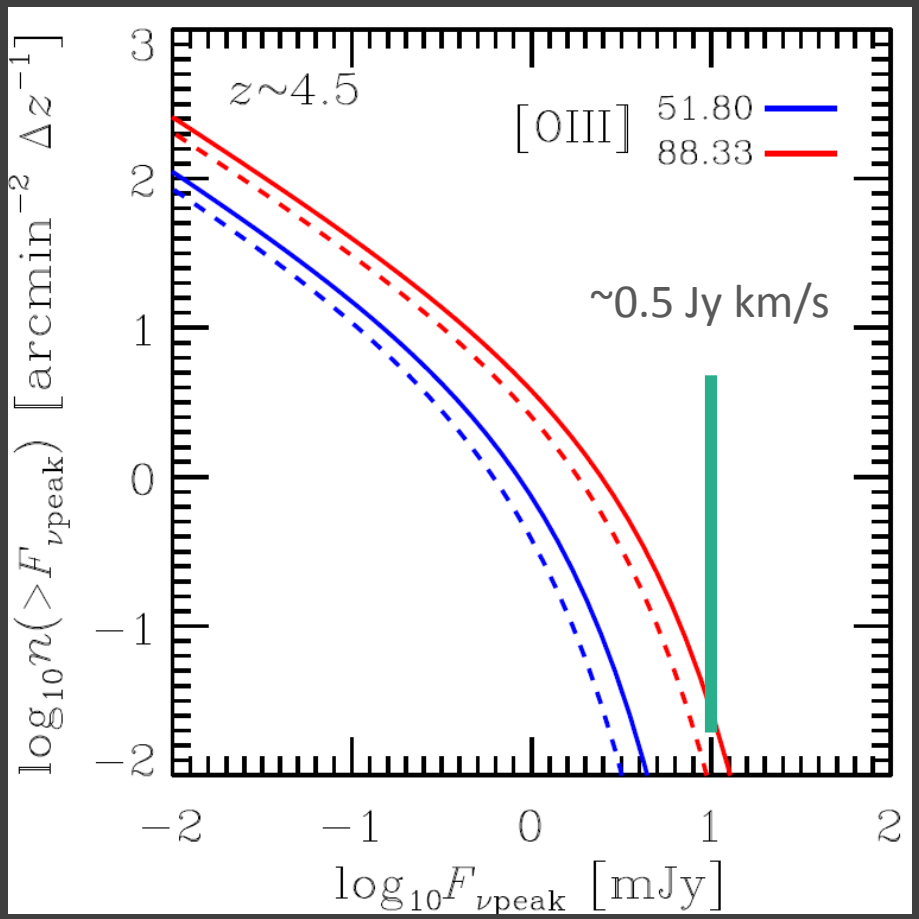


1500 GHz
850 GHz

UV LF: Cucciati et al. (2013), Bouwens et al. (2015); UV dust correction (Burgarella et al. 2013)
Line emissivity (Inoue et al. 2014) 直線: Z=0.2Zsun, 破線: Z=Zsun, 点線: Z=0.02Zsun
輝線幅Δv=50 km/s

[OIII]52/88輝線予想光度関数

z~4.5

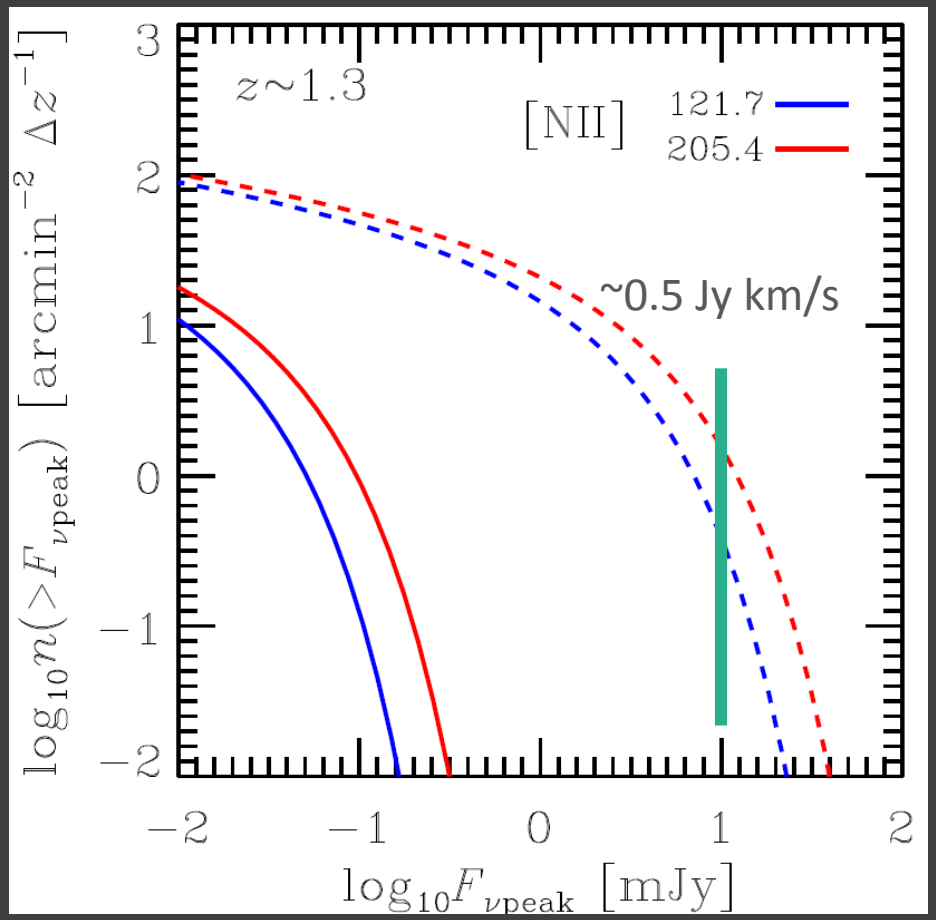


1000 GHz
650 GHz

UV LF: Cucciati et al. (2013), Bouwens et al. (2015); UV dust correction (Burgarella et al. 2013)
Line emissivity (Inoue et al. 2014) 直線: Z=0.2Zsun, 破線: Z=Zsun, 点線: Z=0.02Zsun
輝線幅Δv=50 km/s

[NII]122/205輝線予想光度関数

z~1.3

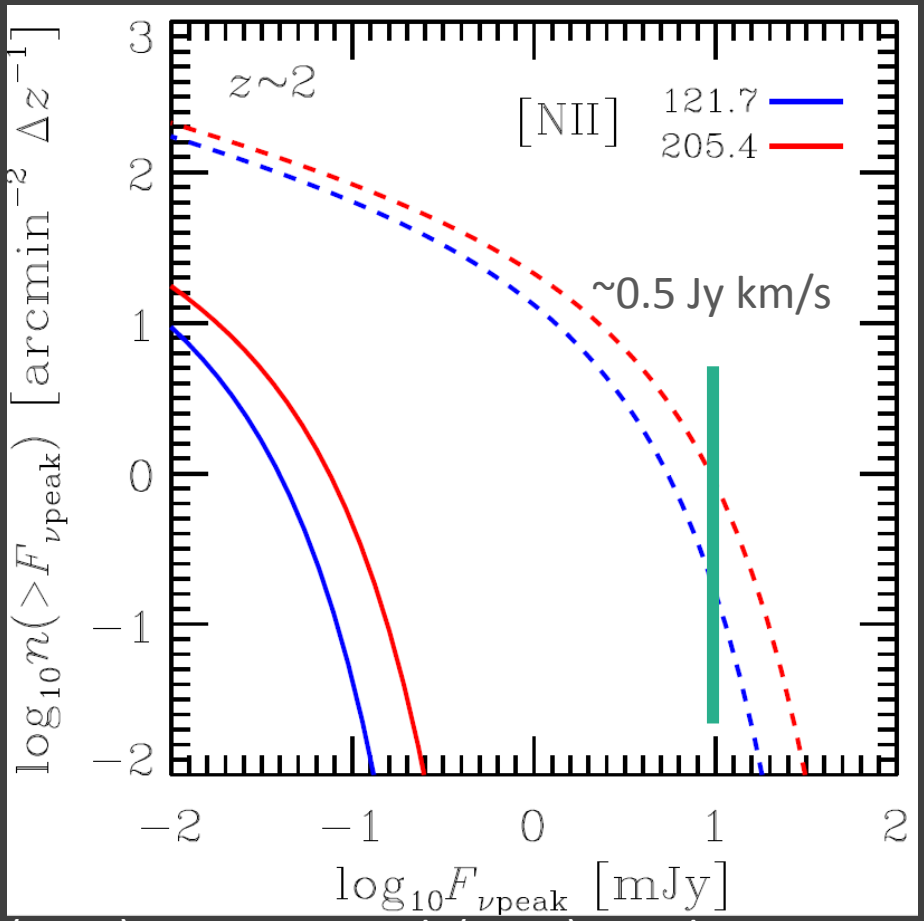


1000 GHz
650 GHz

UV LF: Cucciati et al. (2013), Bouwens et al. (2015); UV dust correction (Burgarella et al. 2013)
Line emissivity (Inoue et al. 2014) 直線: Z=0.2Zsun, 破線: Z=Zsun, 点線: Z=0.02Zsun
輝線幅Δv=50 km/s

[NII]122/205輝線予想光度関数

z~2

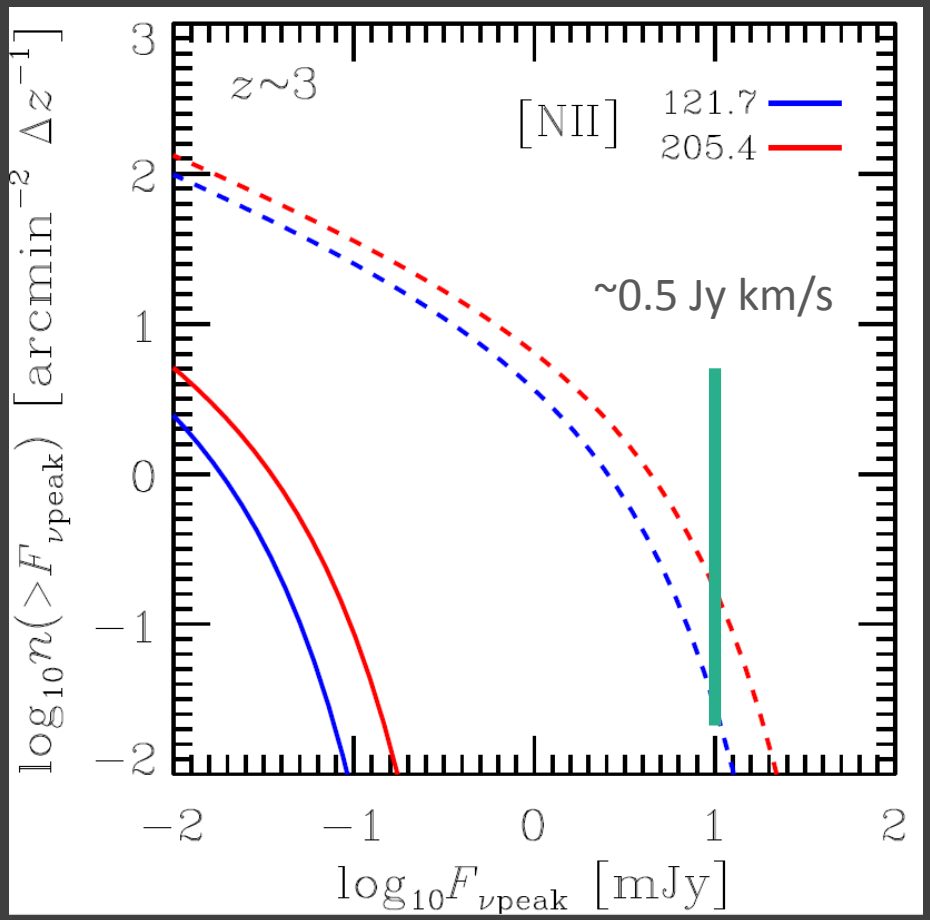


850 GHz
450 GHz

UV LF: Cucciati et al. (2013), Bouwens et al. (2015); UV dust correction (Burgarella et al. 2013)
Line emissivity (Inoue et al. 2014) 直線: Z=0.2Zsun, 破線: Z=Zsun, 点線: Z=0.02Zsun
輝線幅Δv=50 km/s

[NII]122/205輝線予想光度関数

z~3



650 GHz
350 GHz

UV LF: Cucciati et al. (2013), Bouwens et al. (2015); UV dust correction (Burgarella et al. 2013)
Line emissivity (Inoue et al. 2014) 直線: Z=0.2Zsun, 破線: Z=Zsun, 点線: Z=0.02Zsun
輝線幅Δv=50 km/s

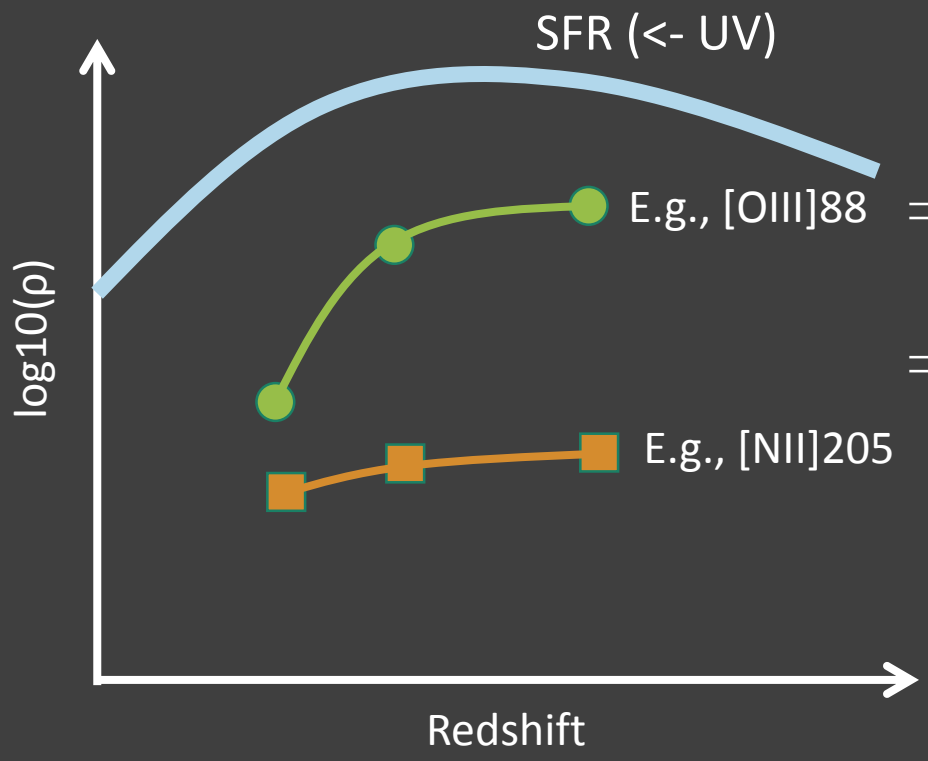
予想検出個数

>~0.5 Jy km/s, 100 arcmin2, dz=0.1

Line/ Redshift	[OIII]52 (Z=Zsun)	(Z=0.2Zsun)	[OIII]88 (Z=Zsun)	(Z=0.2Zsun)
z~3	~1	~2	~10	~20
z~4.5	~1e-4	~1e-3	~0.1	~0.2

Line/ Redshift	[NII]122 (Z=Zsun)	(Z=0.2Zsun)	[NII]205 (Z=Zsun)	(Z=0.2Zsun)
z~1.3	~4	0	~20	0
z~2	~1	0	~6	0
z~3	~0.3	0	~1	0

議論 : 輝線光度密度(比)の進化

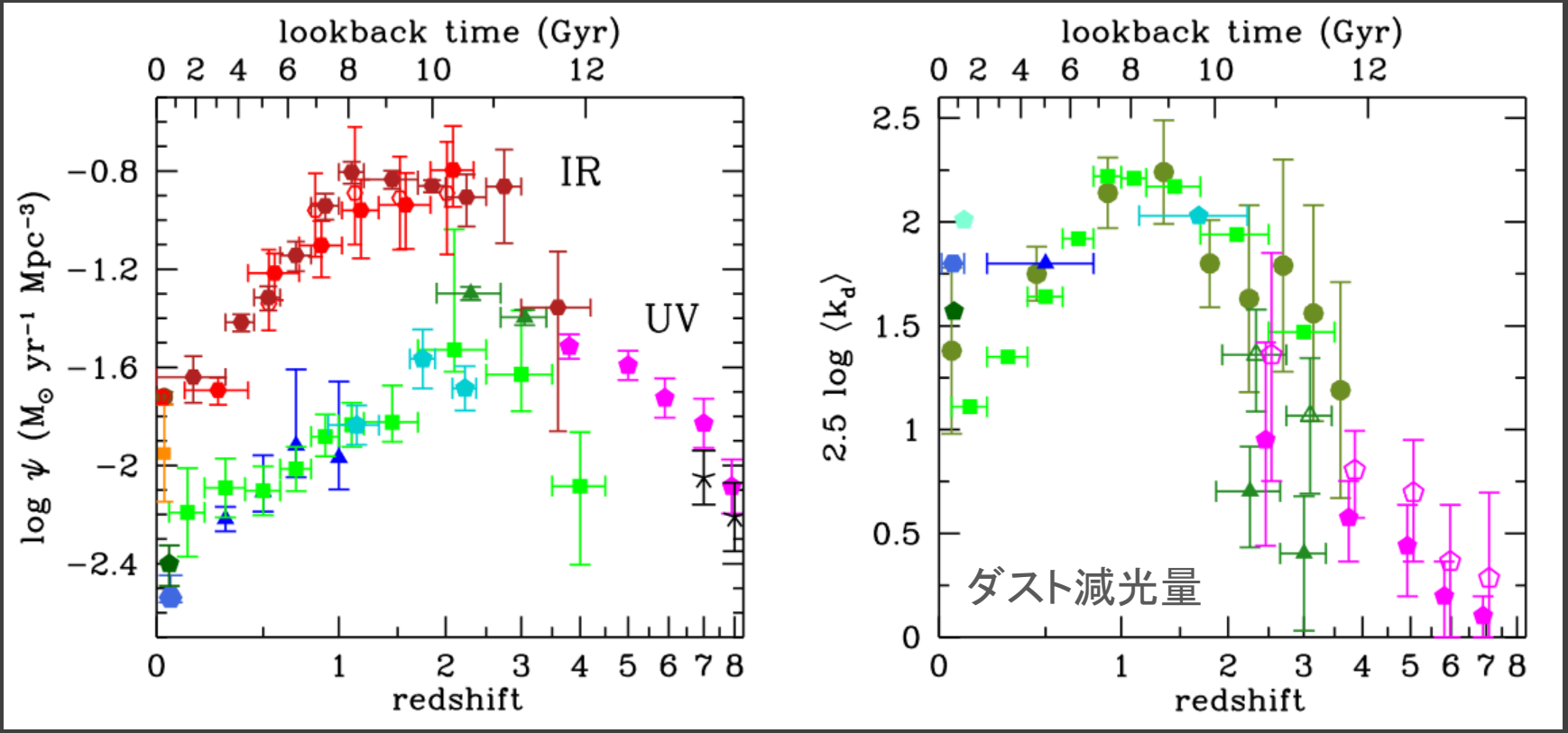


⇒ Ionizing emissivity evolution
(Cosmic reionization)

⇒ N/O abundance evolution
(Cosmic chemical evolution)

宇宙の星形成史

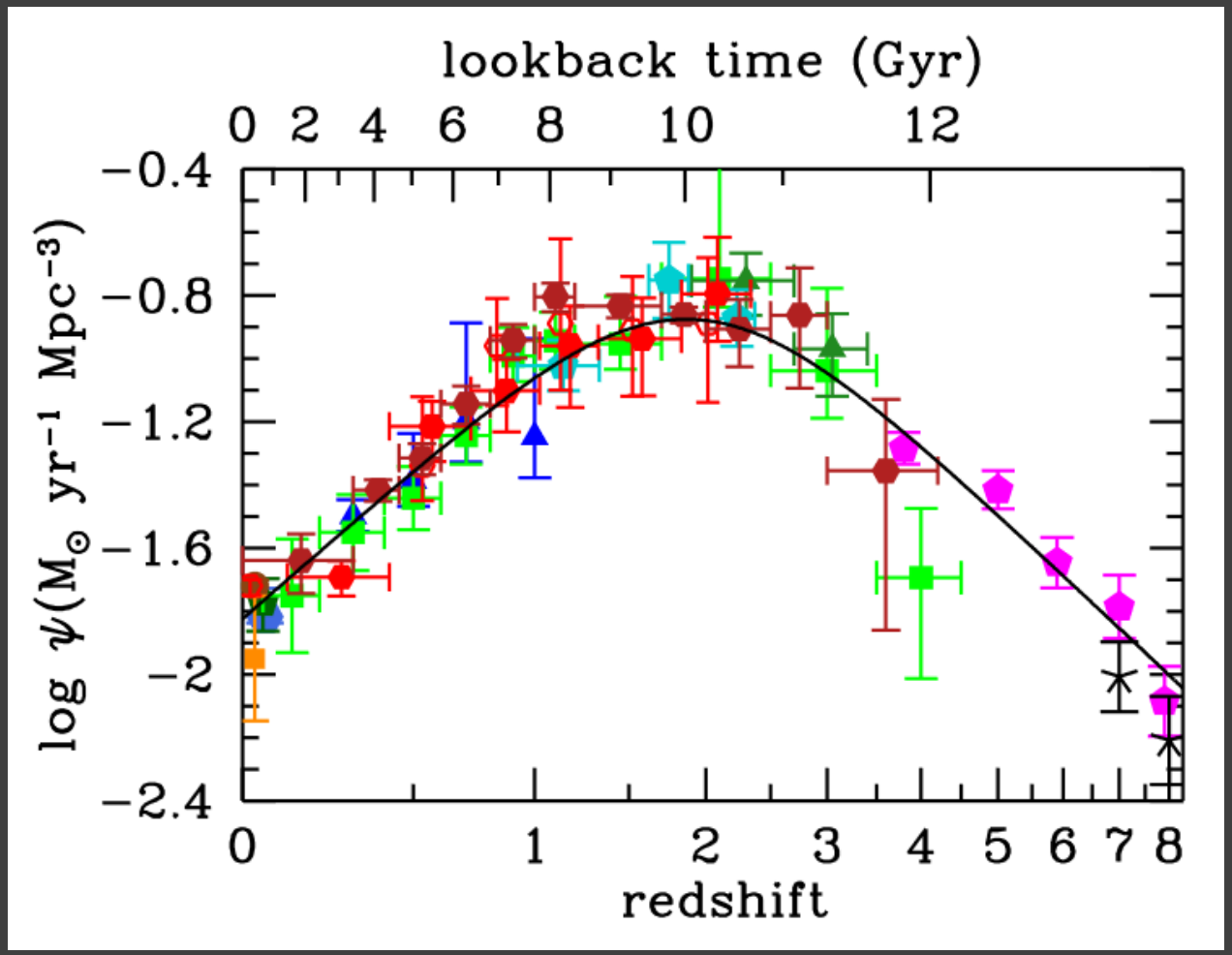
Madau & Dickinson (2014)



オリーブ色は紫外・赤外光度密度比から、
他は紫外線スペクトルスロープから推定

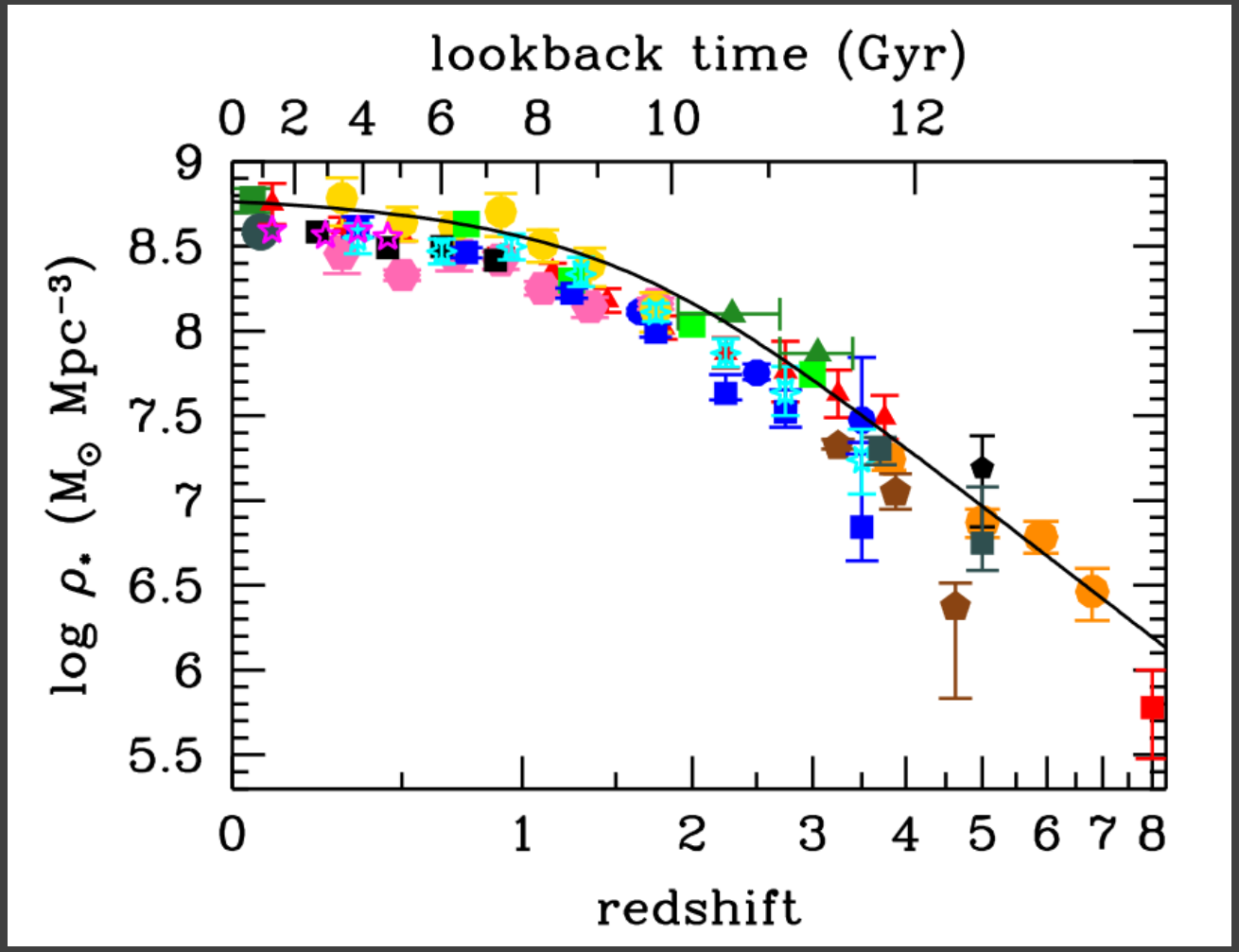
宇宙の星形成史

Madau & Dickinson (2014)



宇宙の恒星質量密度進化史

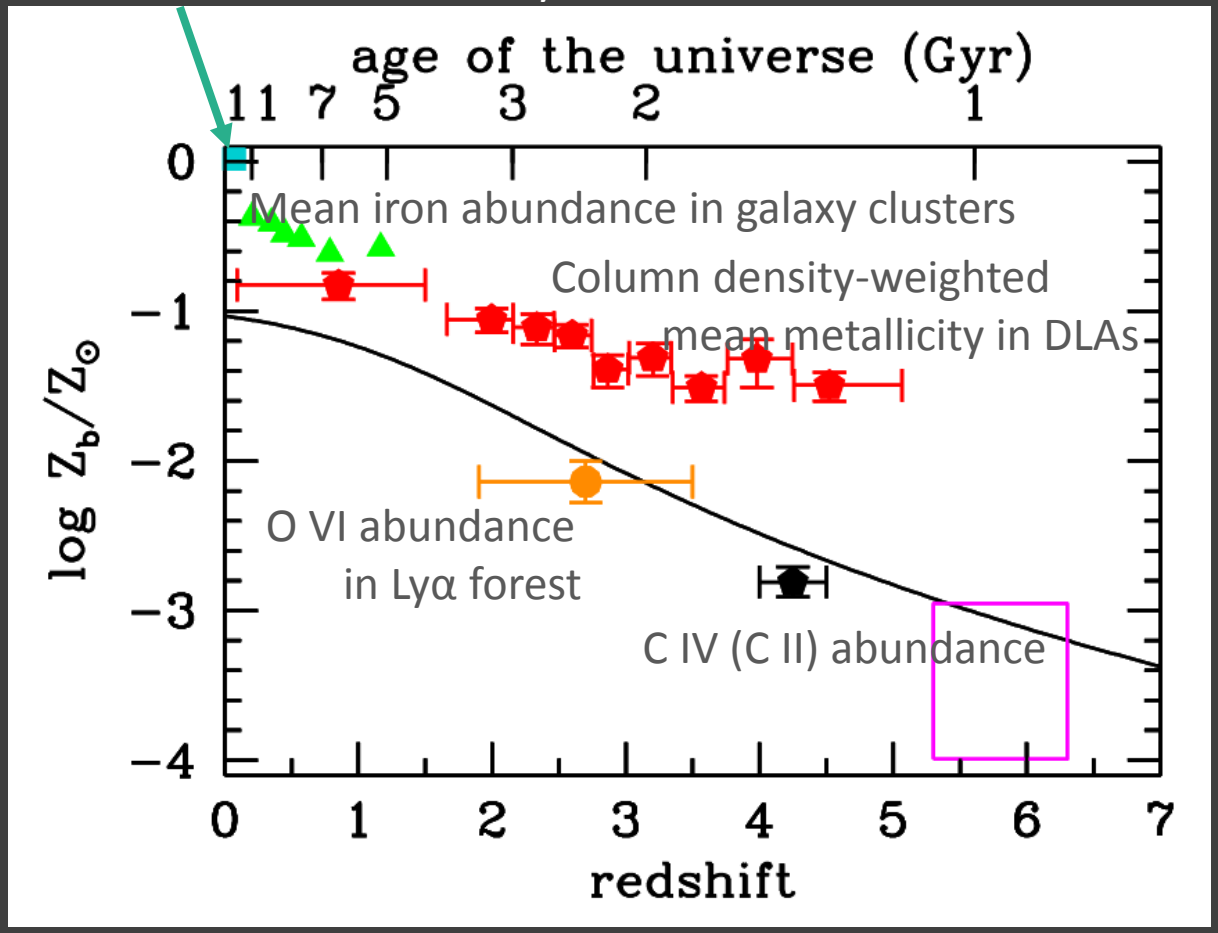
Madau & Dickinson (2014)



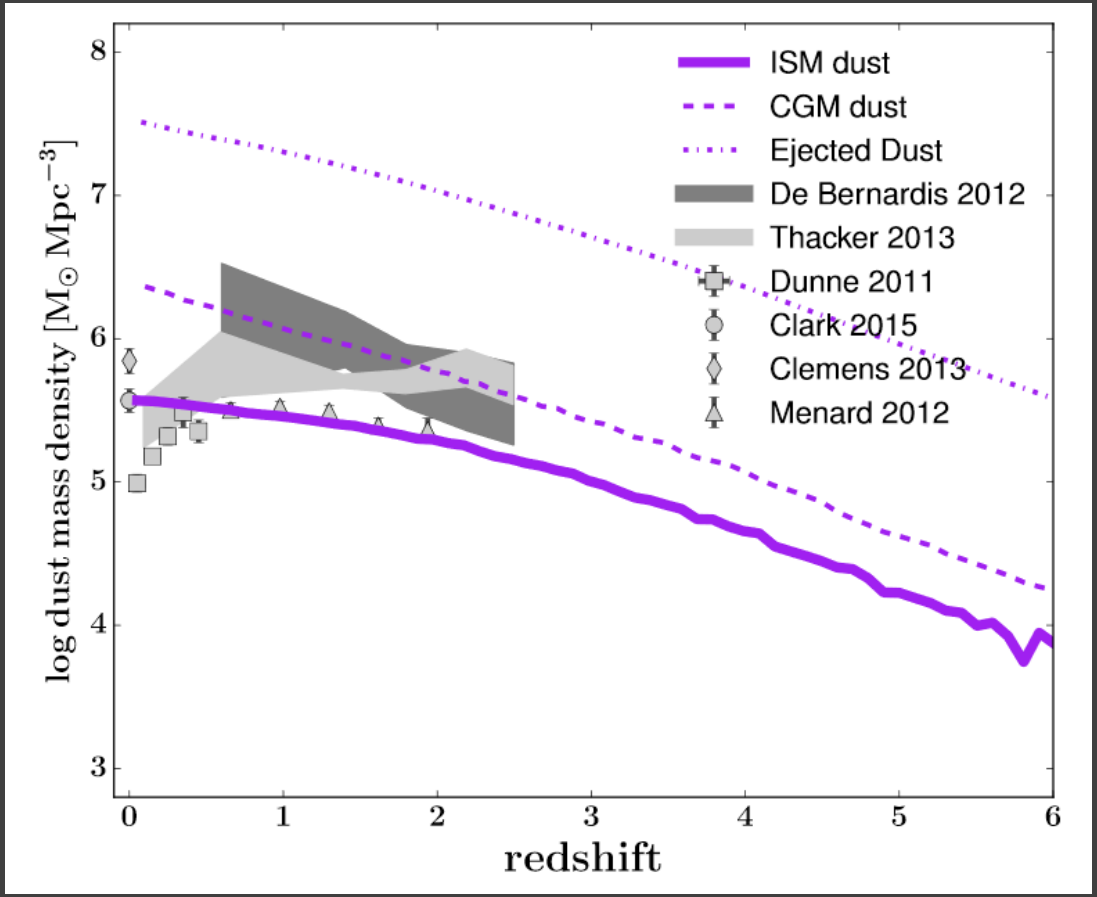
宇宙の金属量進化史

Madau & Dickinson (2014)

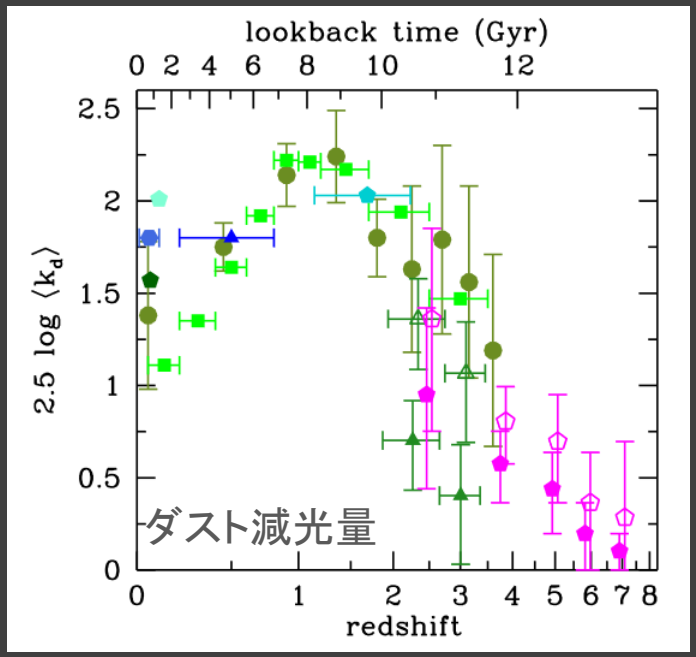
Mass-weighted mean stellar metallicity



宇宙のダスト量進化史



Popping et al. (2017)
Semi-analytical model predictions



オリーブ色は紫外・赤外光度密度比から、
他は紫外線スペクトルスロープから推定
Madau & Dickinson (2014)