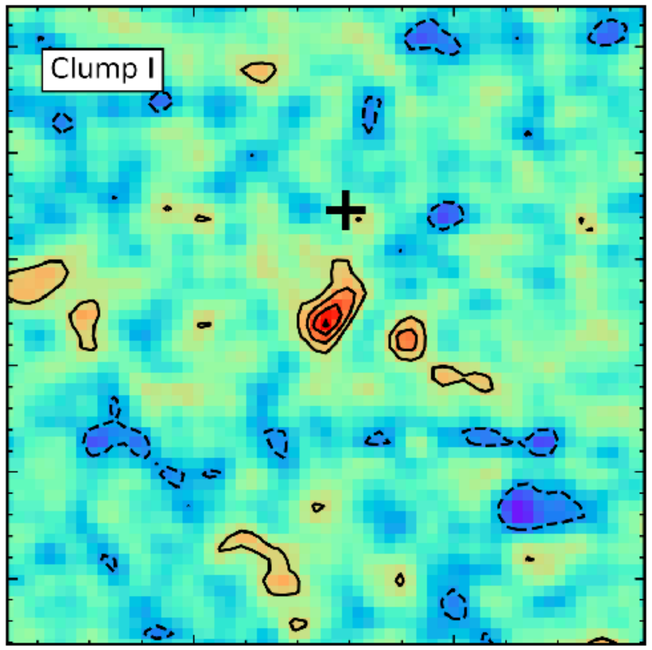
宇宙論シミュレーションによる
遠方[OIII]銀河の観測予測

Moriwaki et al., 2018, MNRAS, 481, L84

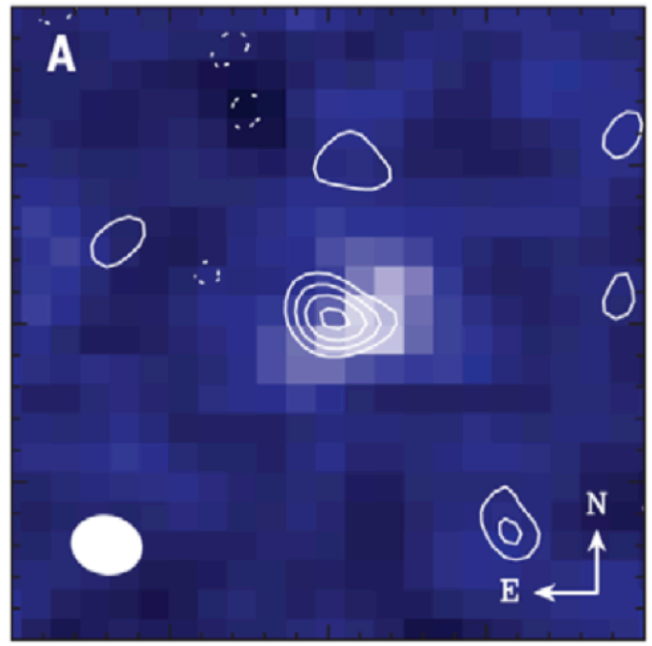
Kana Moriwaki (UTokyo)
Supervisor: Naoki Yoshida

Recent Observation of z > 7 [OIII]88μm with ALMA

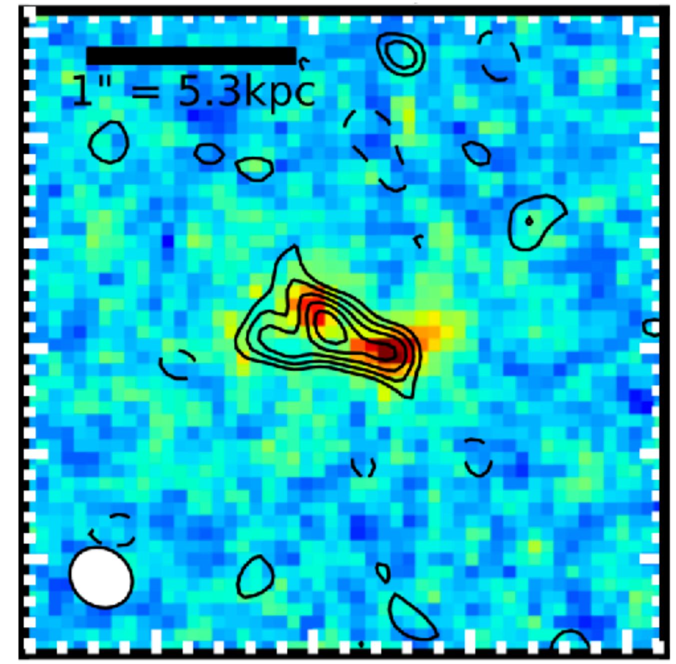
Carniani+ 17
z = 7.1



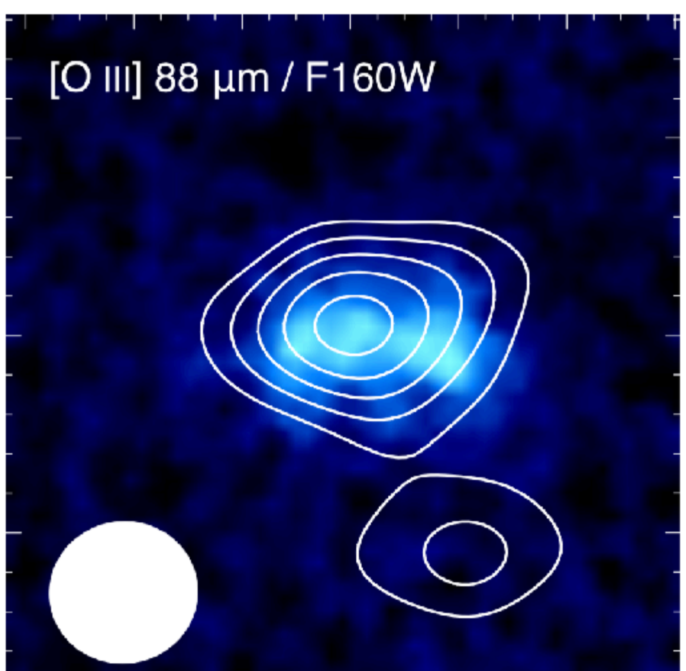
Inoue+ 16
z = 7.2



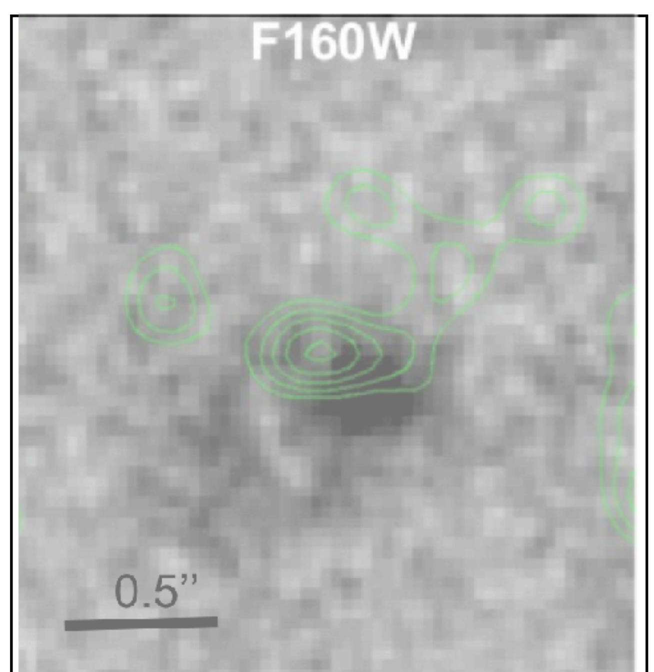
Hashimoto+ 18b
z = 7.2



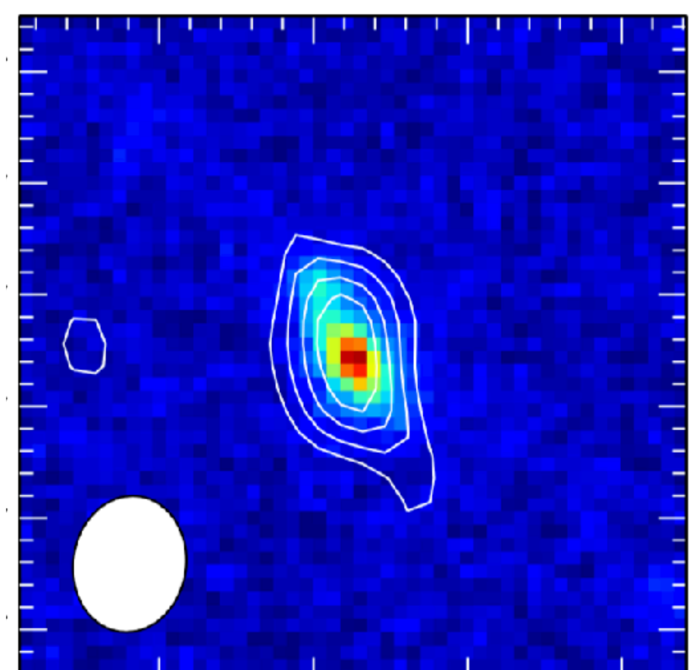
Tamura+ 18
z = 8.3



Laporte+ 17
z = 8.4



Hashimoto+ 18a
z = 9.1



Recent Observation of z > 7 [OIII]88μm with ALMA

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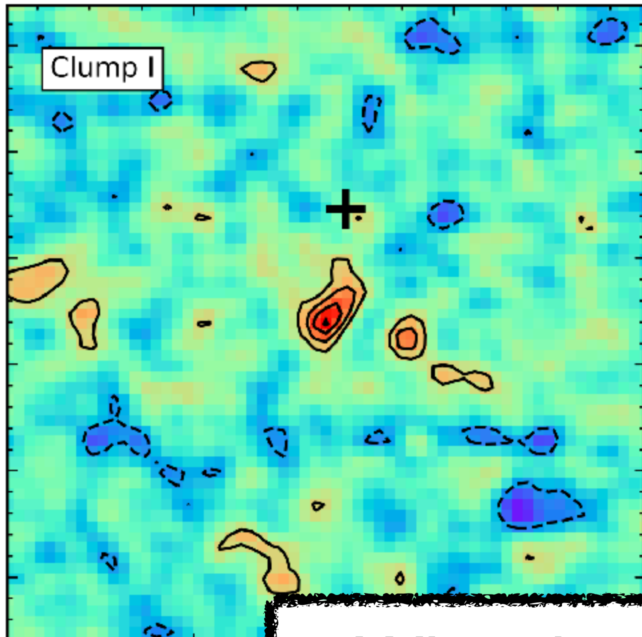

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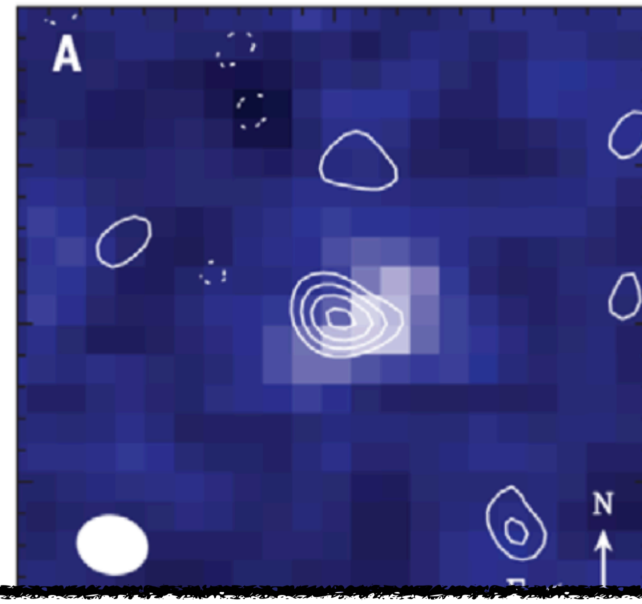

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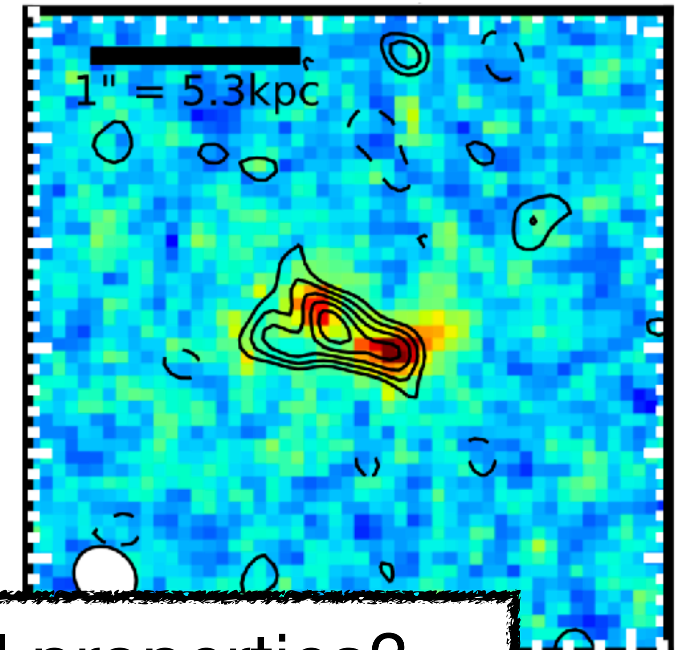
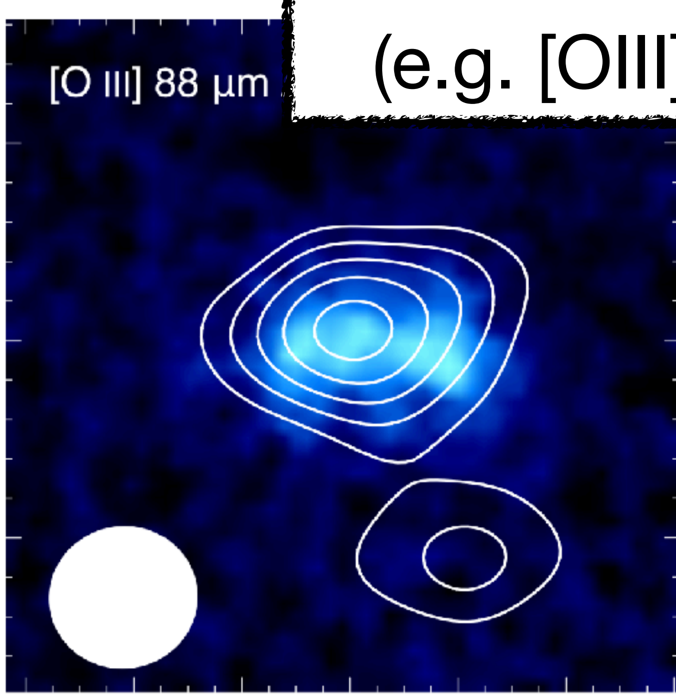
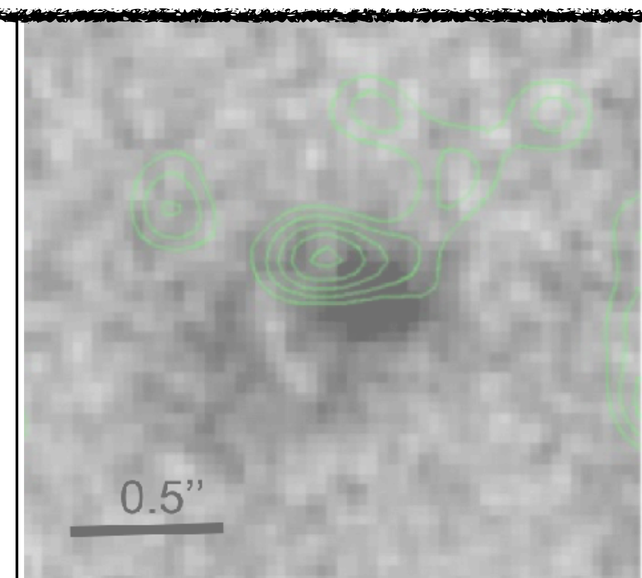


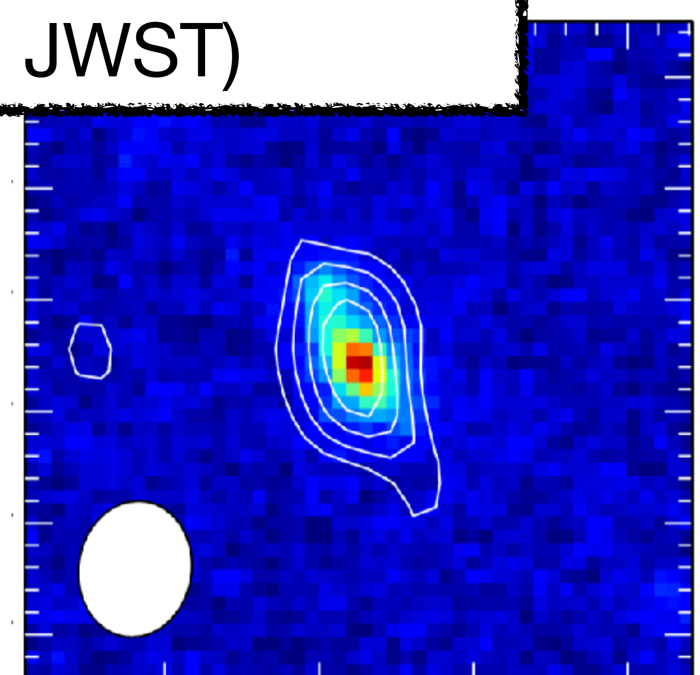
- What is the physical/chemical properties?
- What is expected for future observation?
  (e.g. [OIII] 5007Å @ z > 7 with JWST)

Tam
z

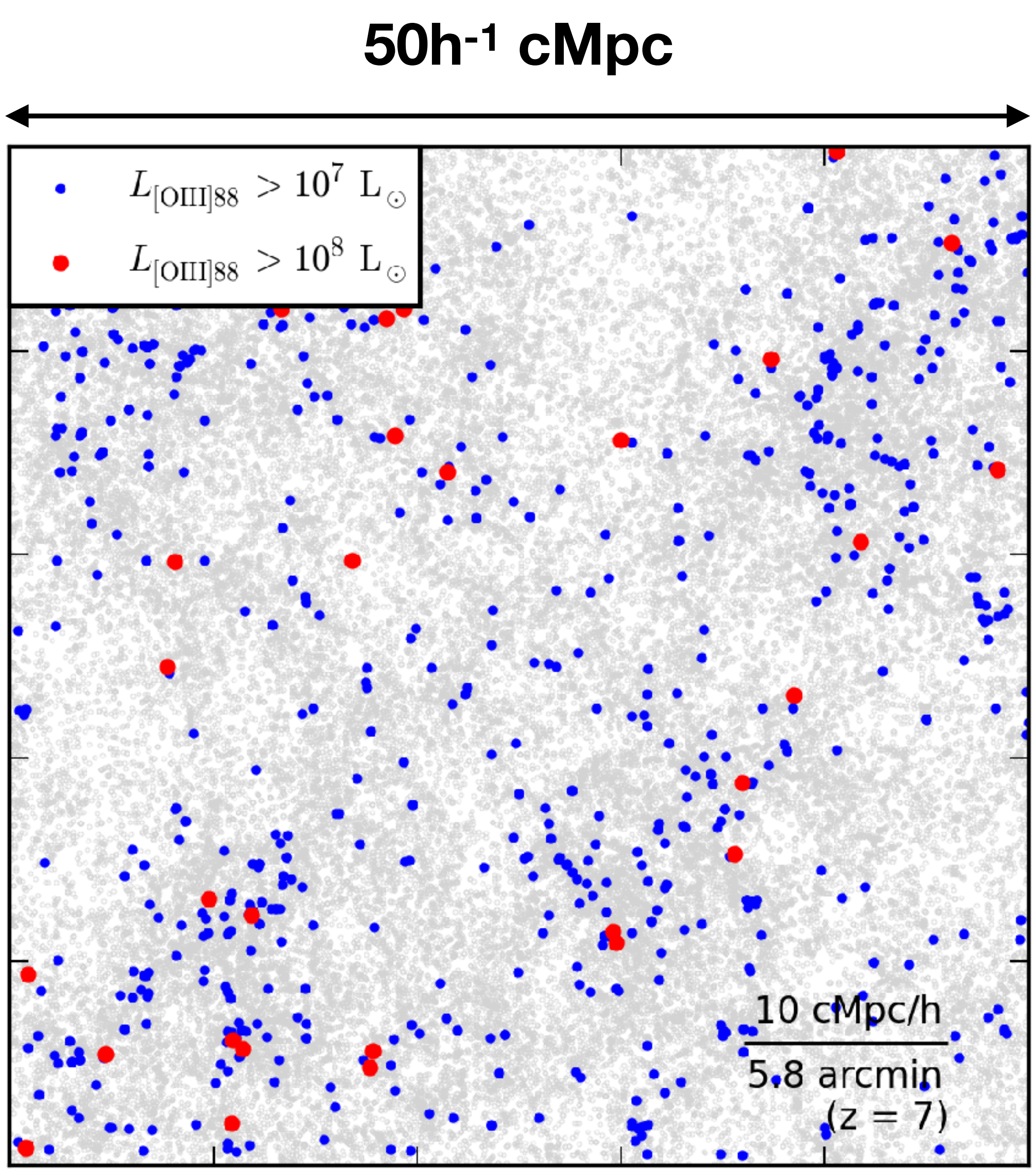
8a







Cosmological Simulation



Shimizu+ 2016

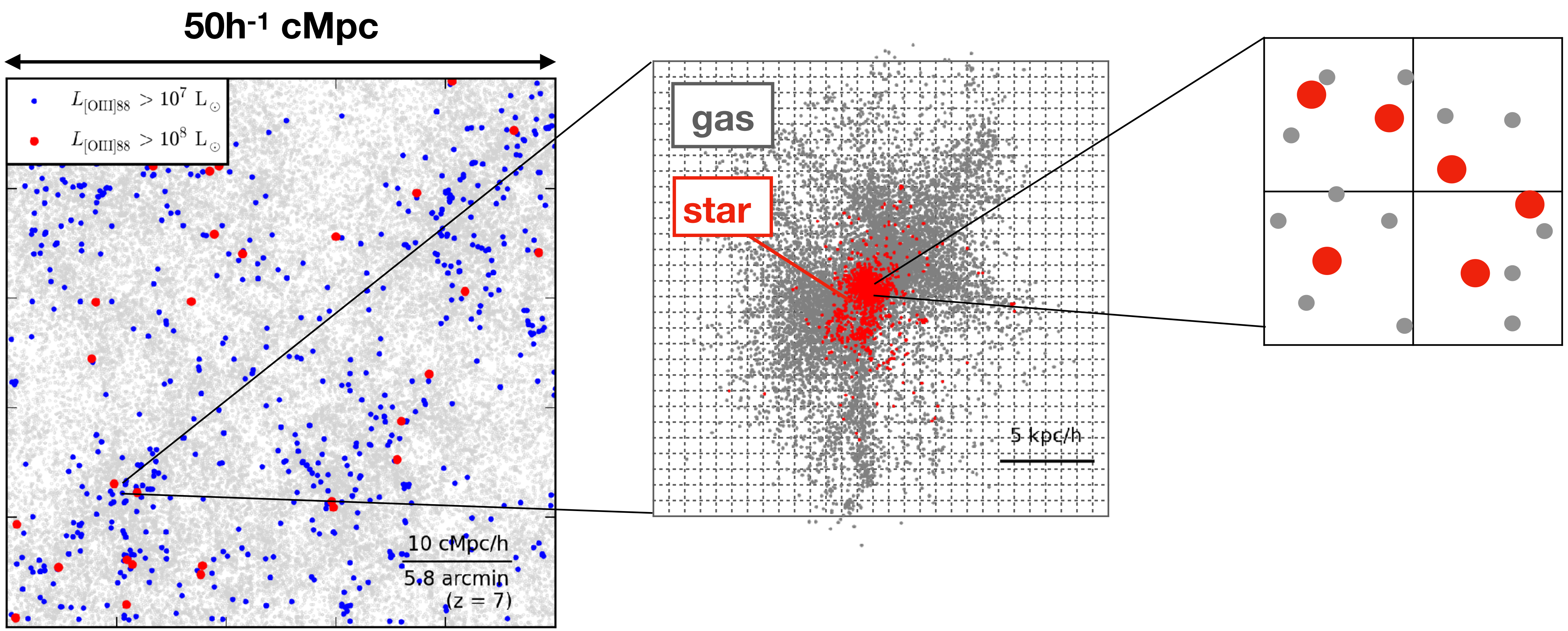
- GADGET-3
- boxsize = $50h^{-1}$ cMpc
- 1280^3 DM/gas particles

- DM particle mass = $4.4 \times 10^6 h^{-1}\ M_\odot$
- gas particle mass = $8.1 \times 10^6 h^{-1}\ M_\odot$
- star particle mass ~ $10^6 h^{-1}\ M_\odot$

- softening length = $2h^{-1}$ckpc

- # of galaxies with $M^* > 10^8\ M_\odot$:
  ~ 30 @ z = 9
  ~ 300 @ z = 7

Line Emission from HII region



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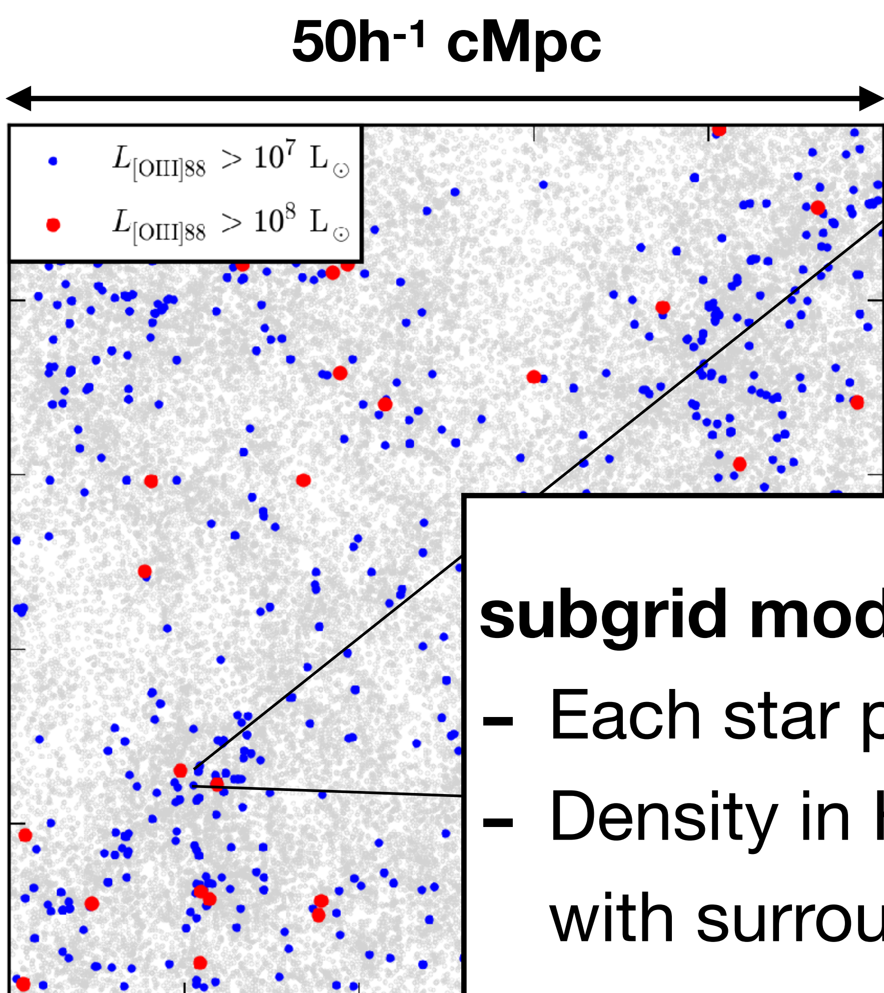
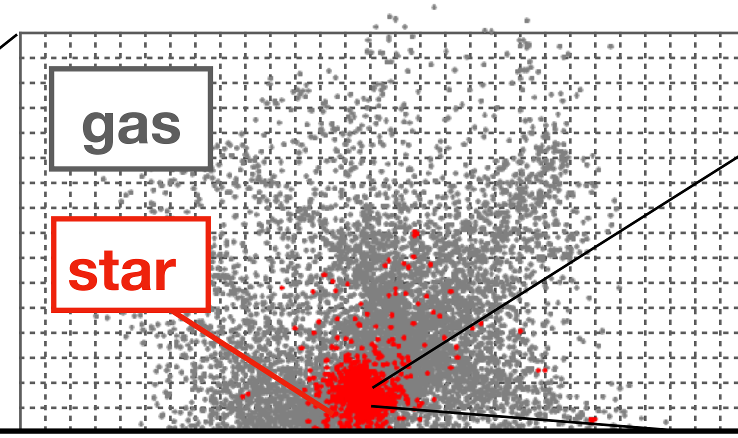
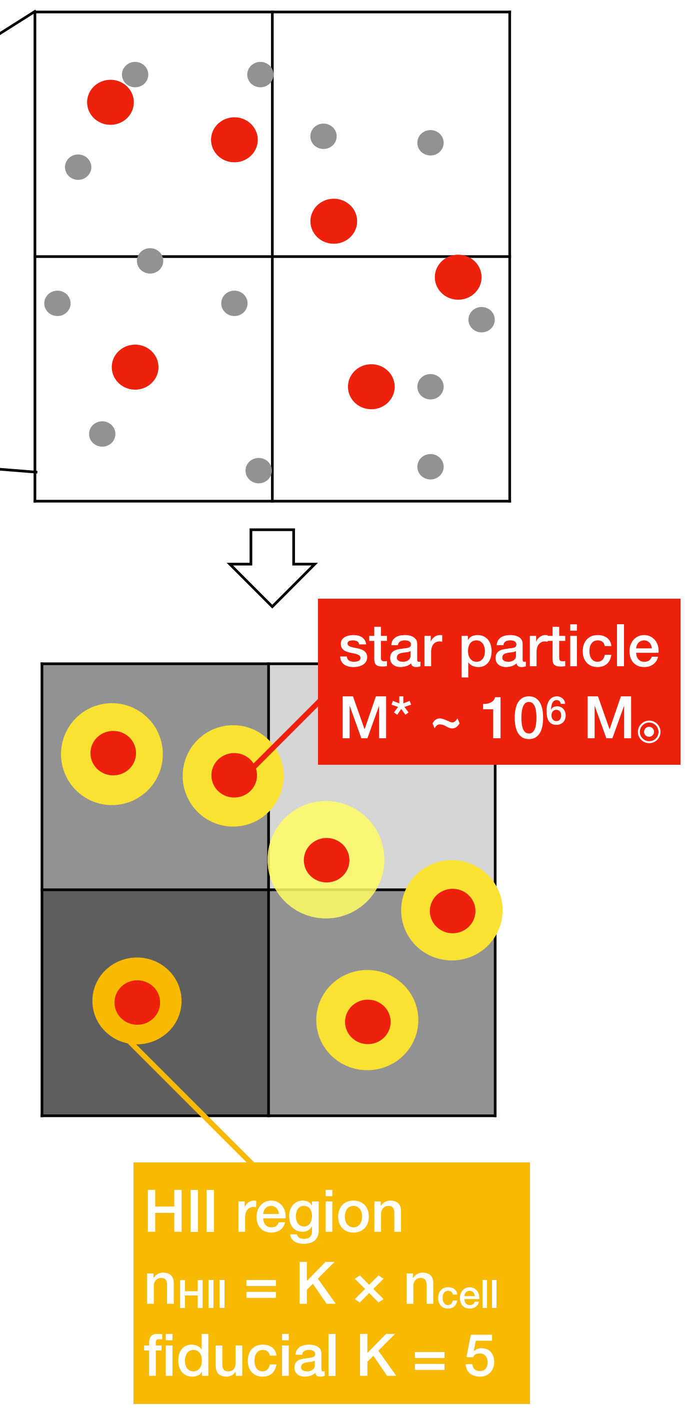






subgrid model

- Each star particle forms a HII region.
- Density in HII region is constant and scales with surrounding gas density.

$$n_{\rm H} = K n_{\rm global}$$

$$\langle U \rangle = \frac{3\alpha_{\rm B}^{2/3}}{4c}\left(\frac{3Qn_{\rm H}}{4\pi}\right)^{1/3}$$

new

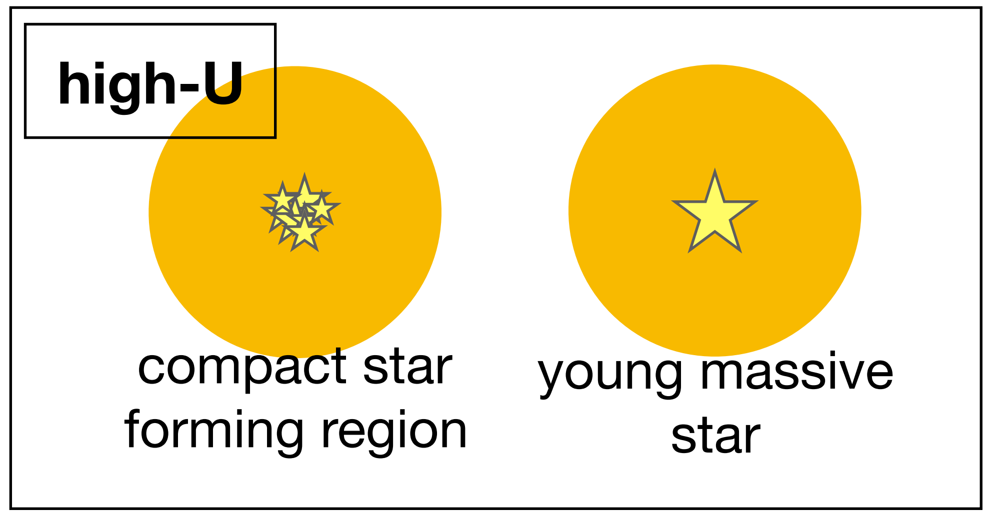
$$L_{\rm line} = C_{\rm line}(Z, n, U) \times L_{\rm H\beta}^{\rm caseB}$$

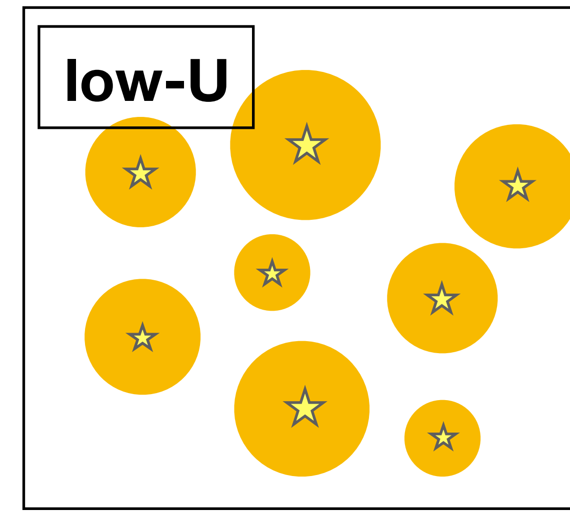
CLOUDY table (cf. Inoue+ 2011)

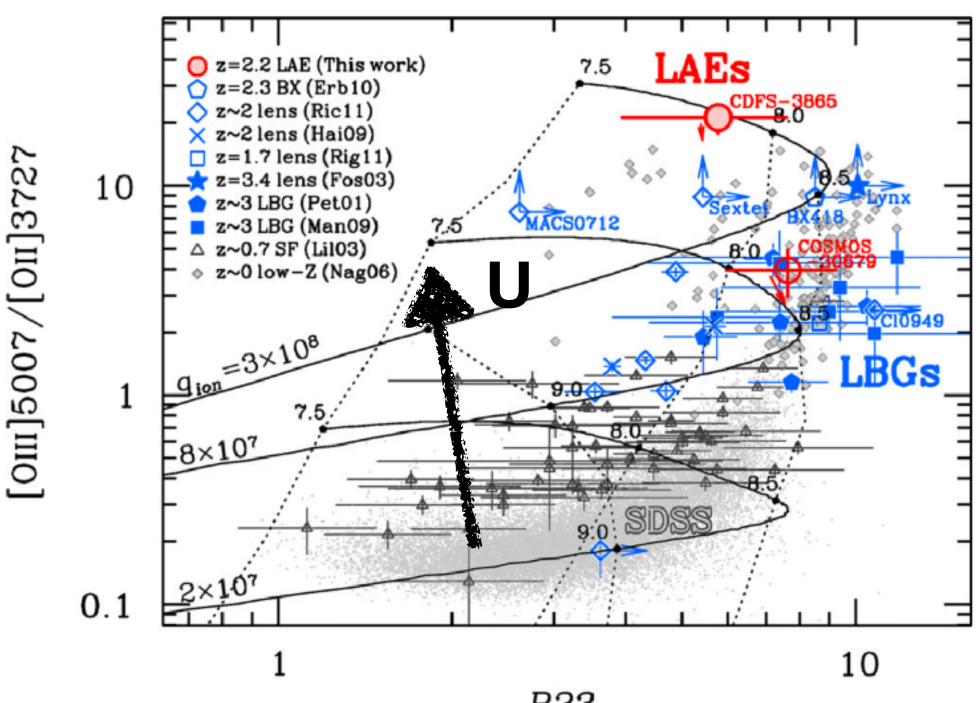
Line Emission from HII region

Why are U and n important?

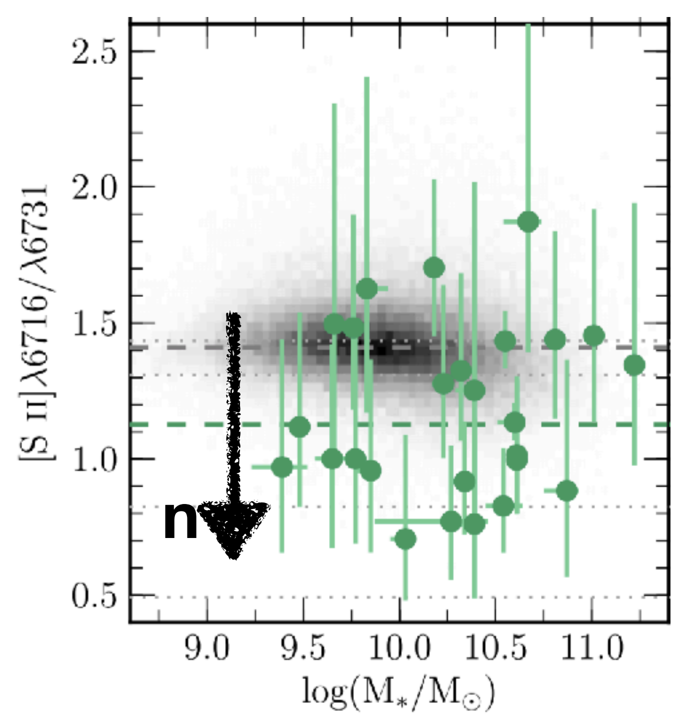
- compactness of star forming region
- ionization bound / density bound HII region
- stellar population
- etc.







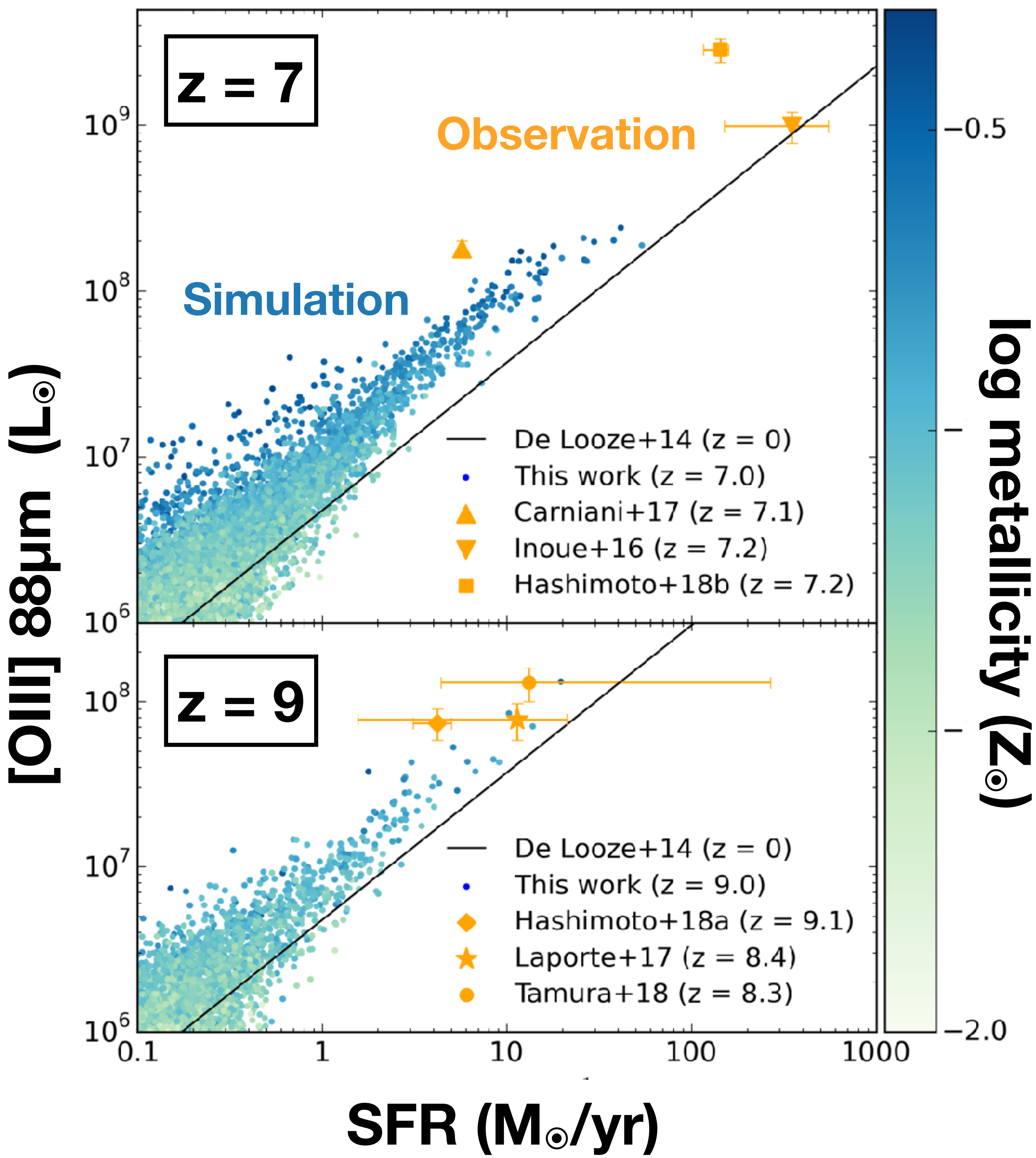
Nakajima+ 2013



Sanders+ 2016

Recent observation suggest the evolution of U and n from z = 0 to z ~ 2-3

Properties of high-z [OIII] emitters



- [OIII] emitters with $L_{OIII88} > 10^8\ L_\odot$:
  - SFR > 3 $M_\odot$/yr
  - Z ~ 0.1 $Z_\odot$

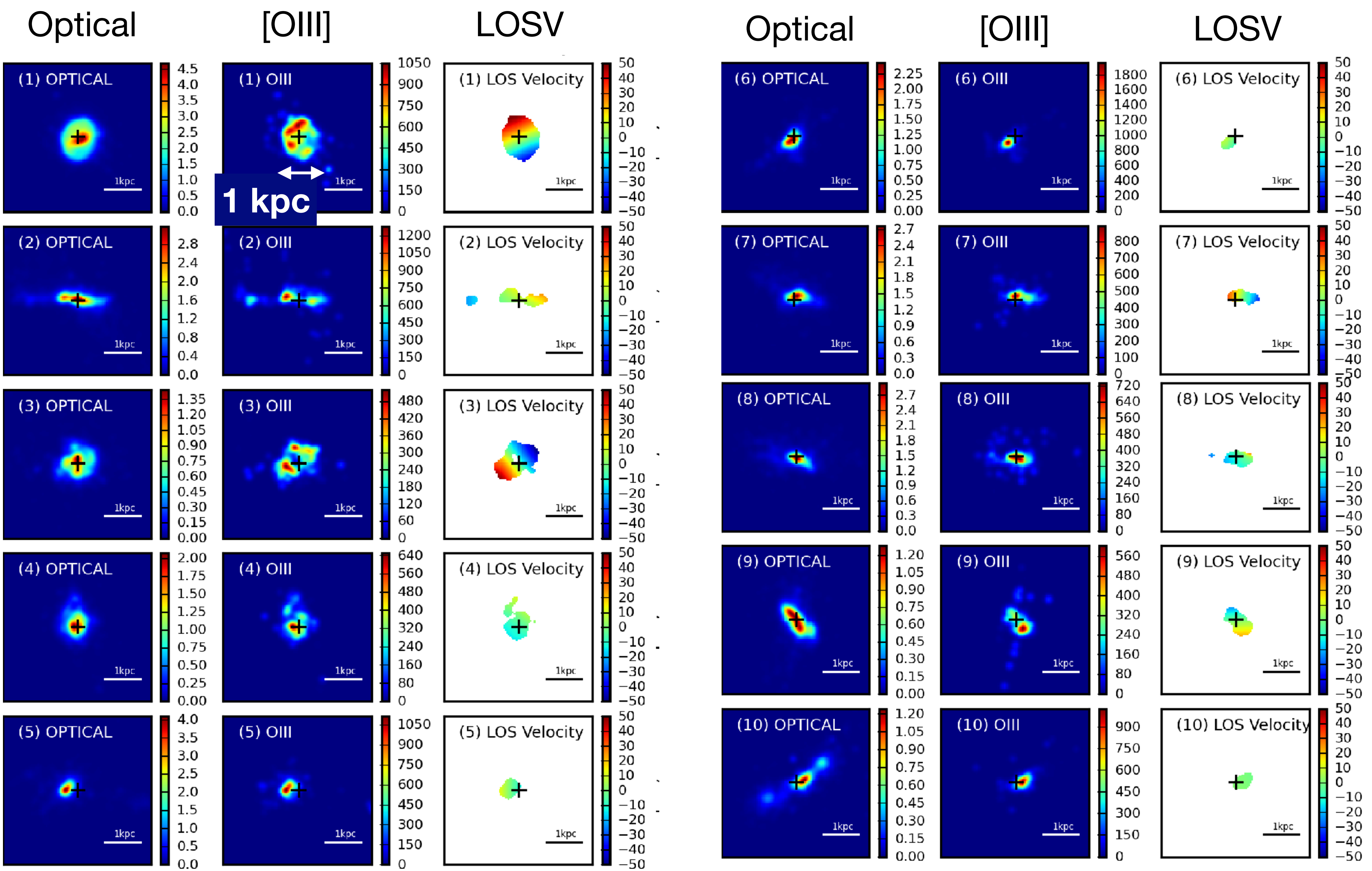
  → **well-established star forming galaxies are selectively observed**

- Higher L_{OIII88} than local galaxies for a given SFR, consistent with recent observations

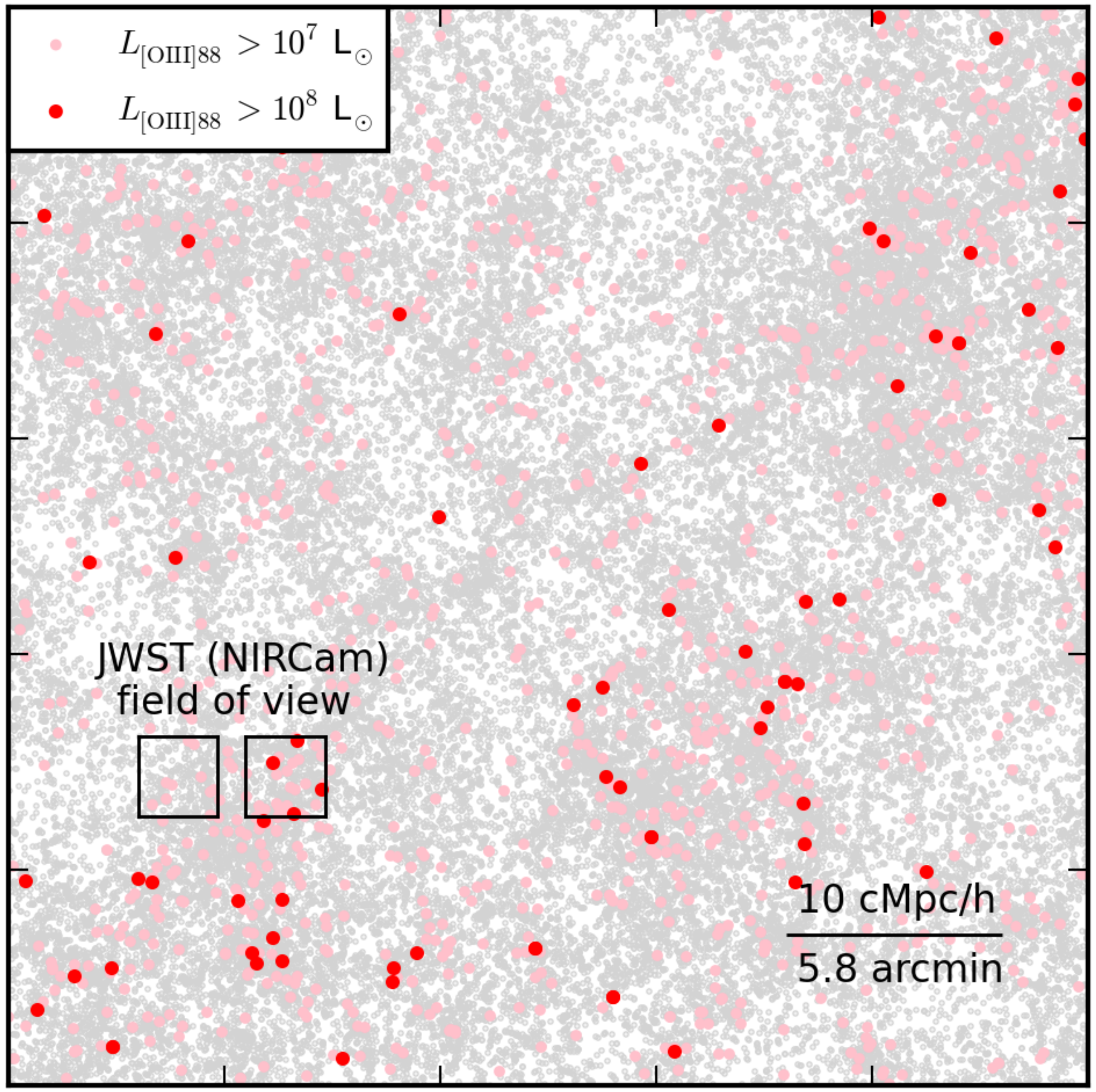
  → **high ionization parameter** (~ 10^{-2} - 10^{-1})

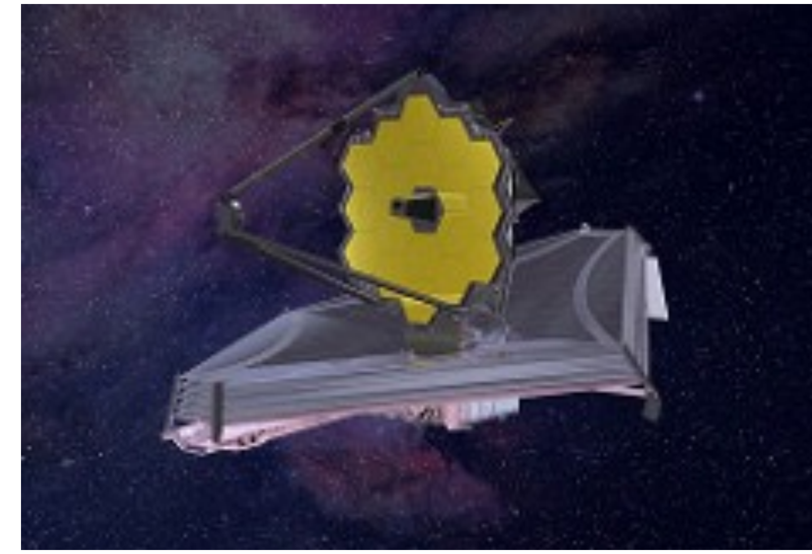
Inner Structure of High-z [OIII] Emitters

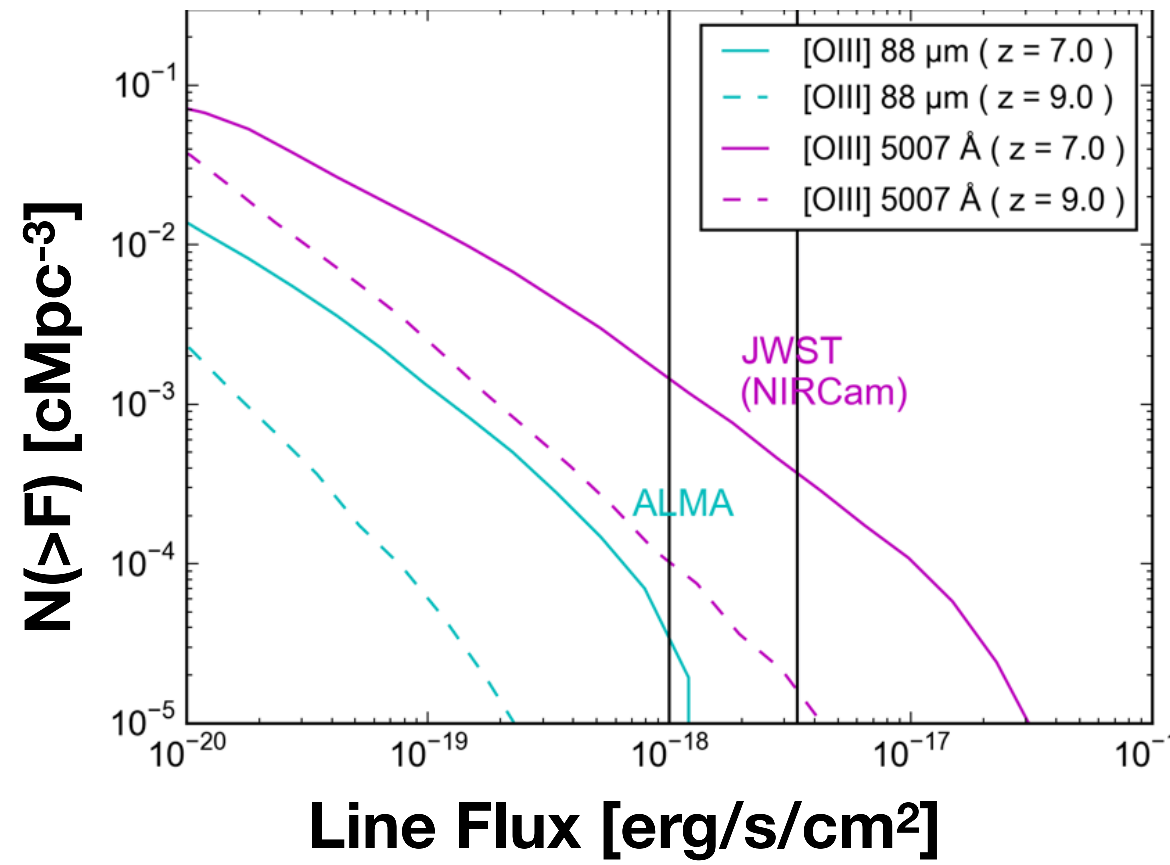
brightest galaxies at z = 9



[OIII] 5007 Å Survey with JWST

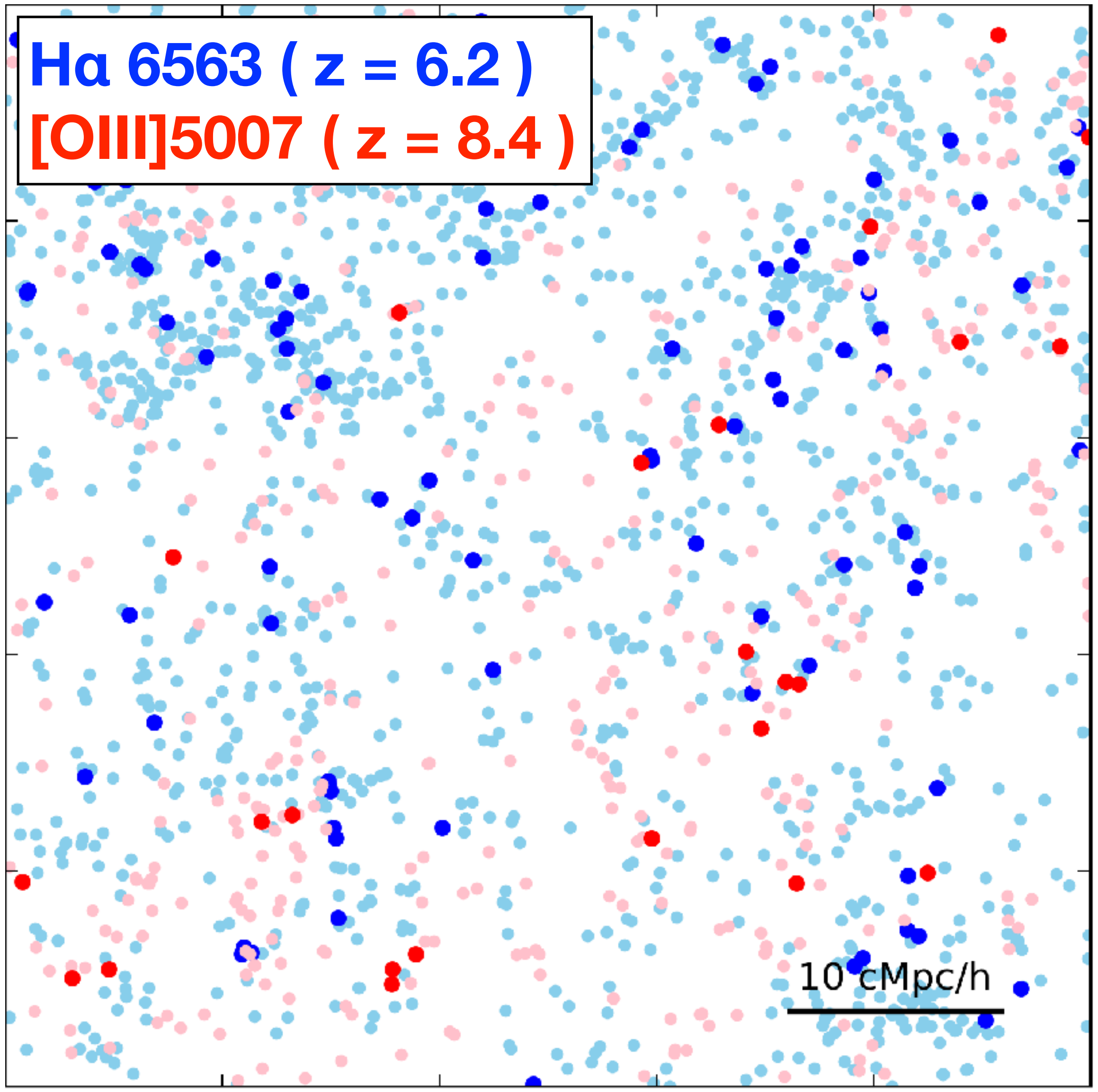


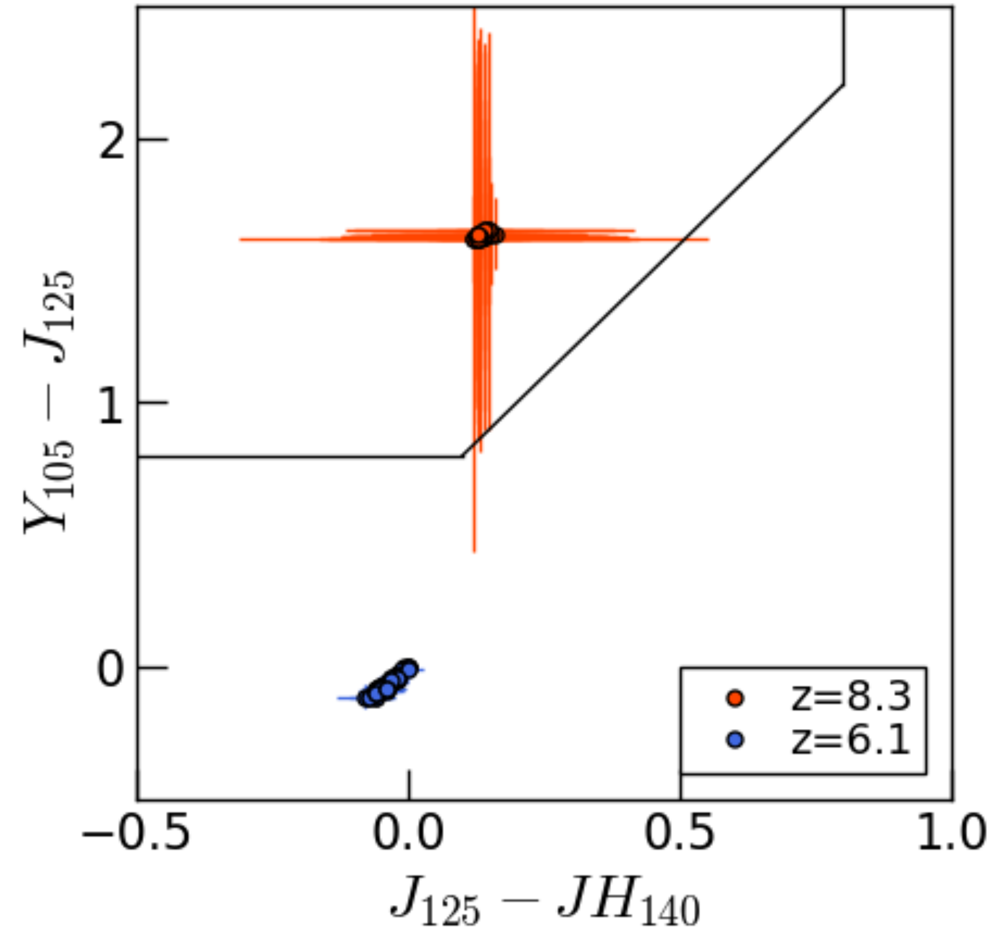


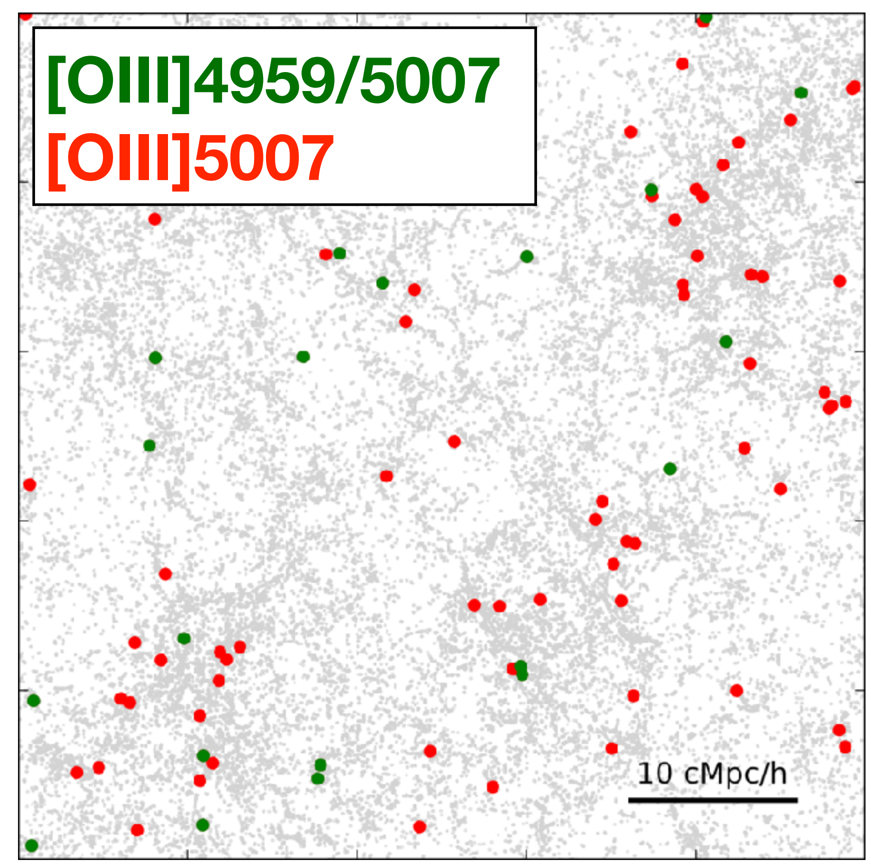


10^5 s (= 10^4 s × 10 FoVs) observations using NIRCam grism mode (z = 6.8-9.0) or NB filter (z ~ 8.4) can detect **20 or 5 [OIII] emitters** with S/N > 5.

[OIII] Survey with JWST?







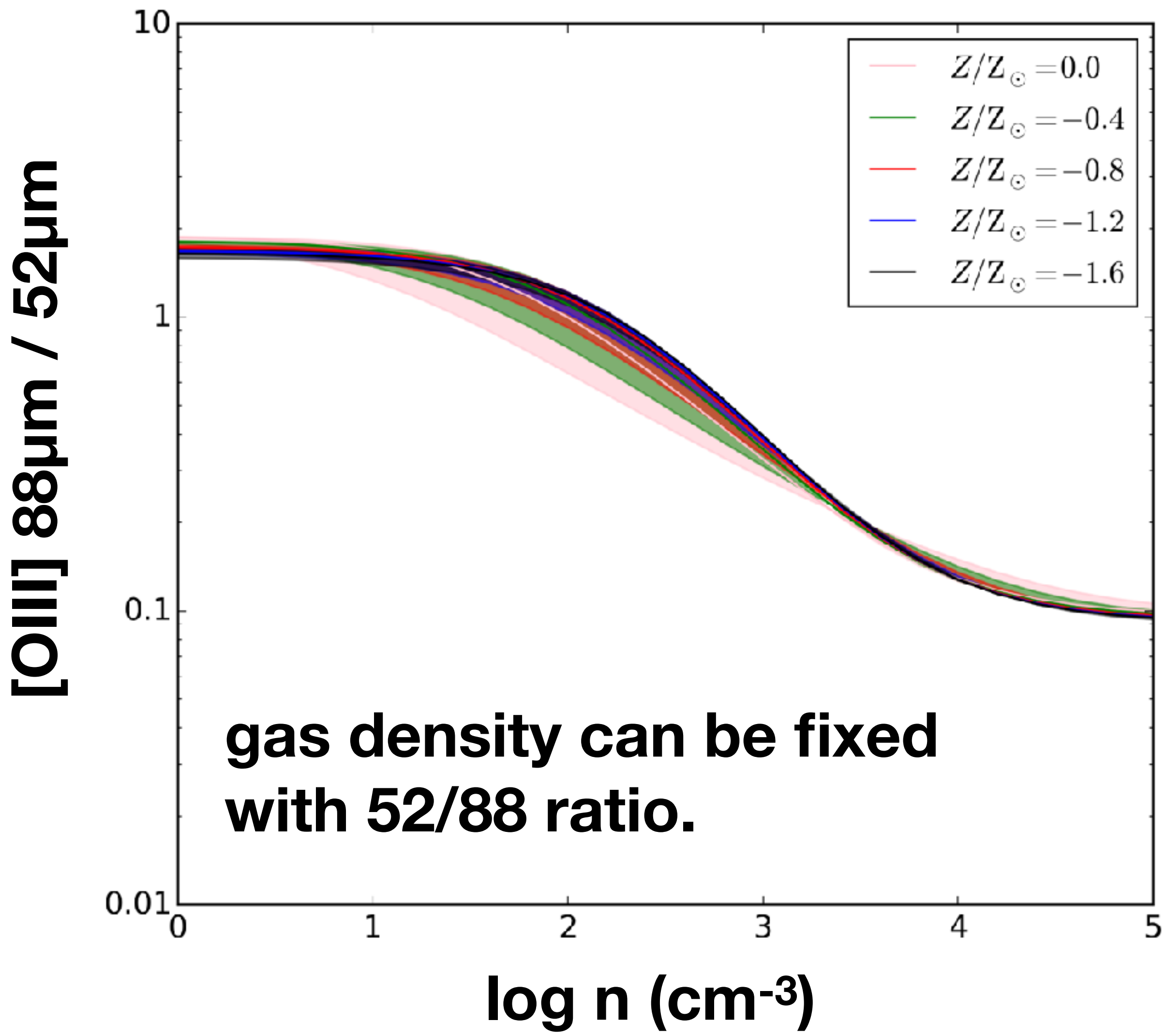
Foreground: Hα @ z = 6.2

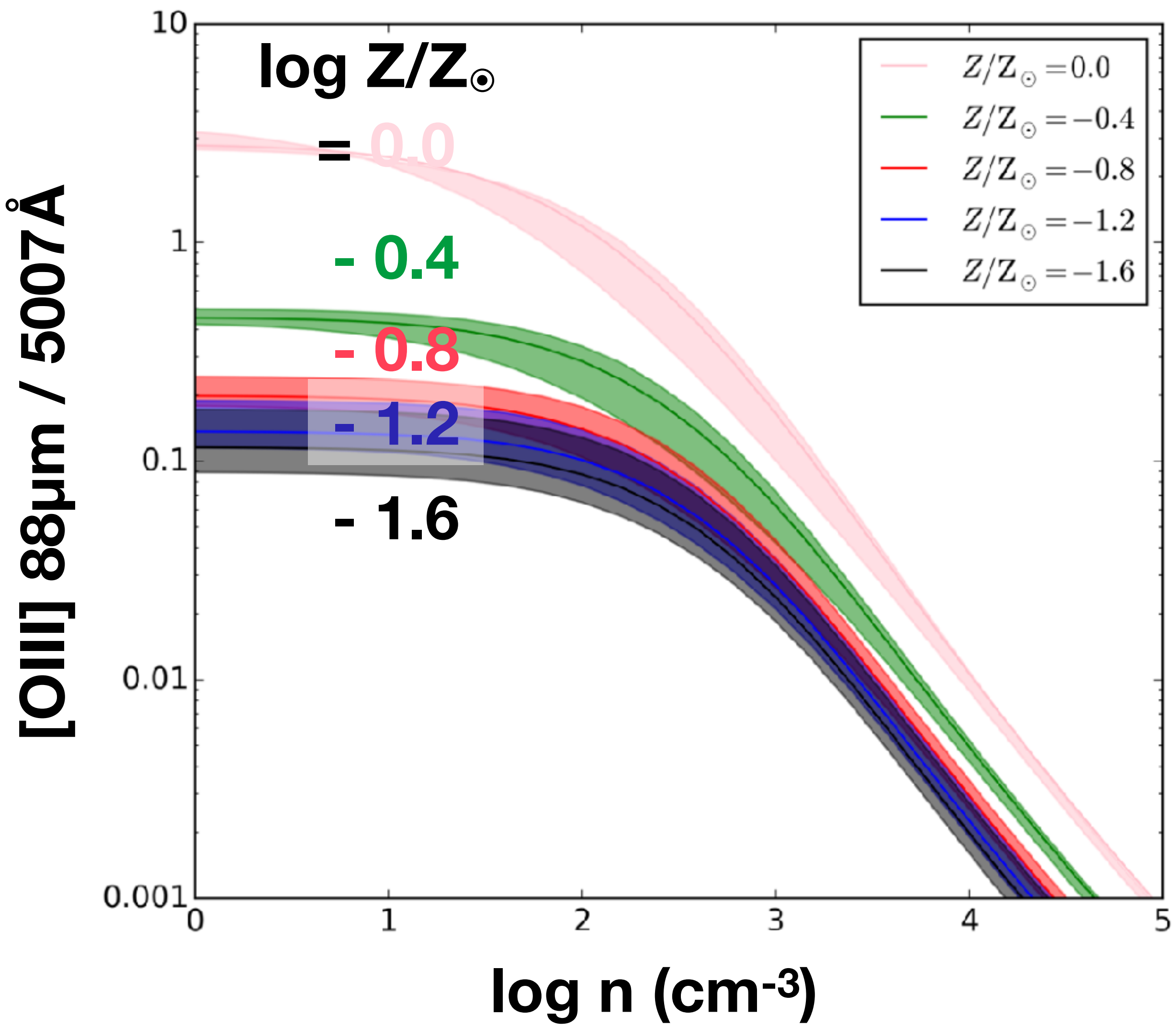
can be distinguished by Y_{105} - J_{125}

and doublet [OIII] 4959Å/5007Å (grism)

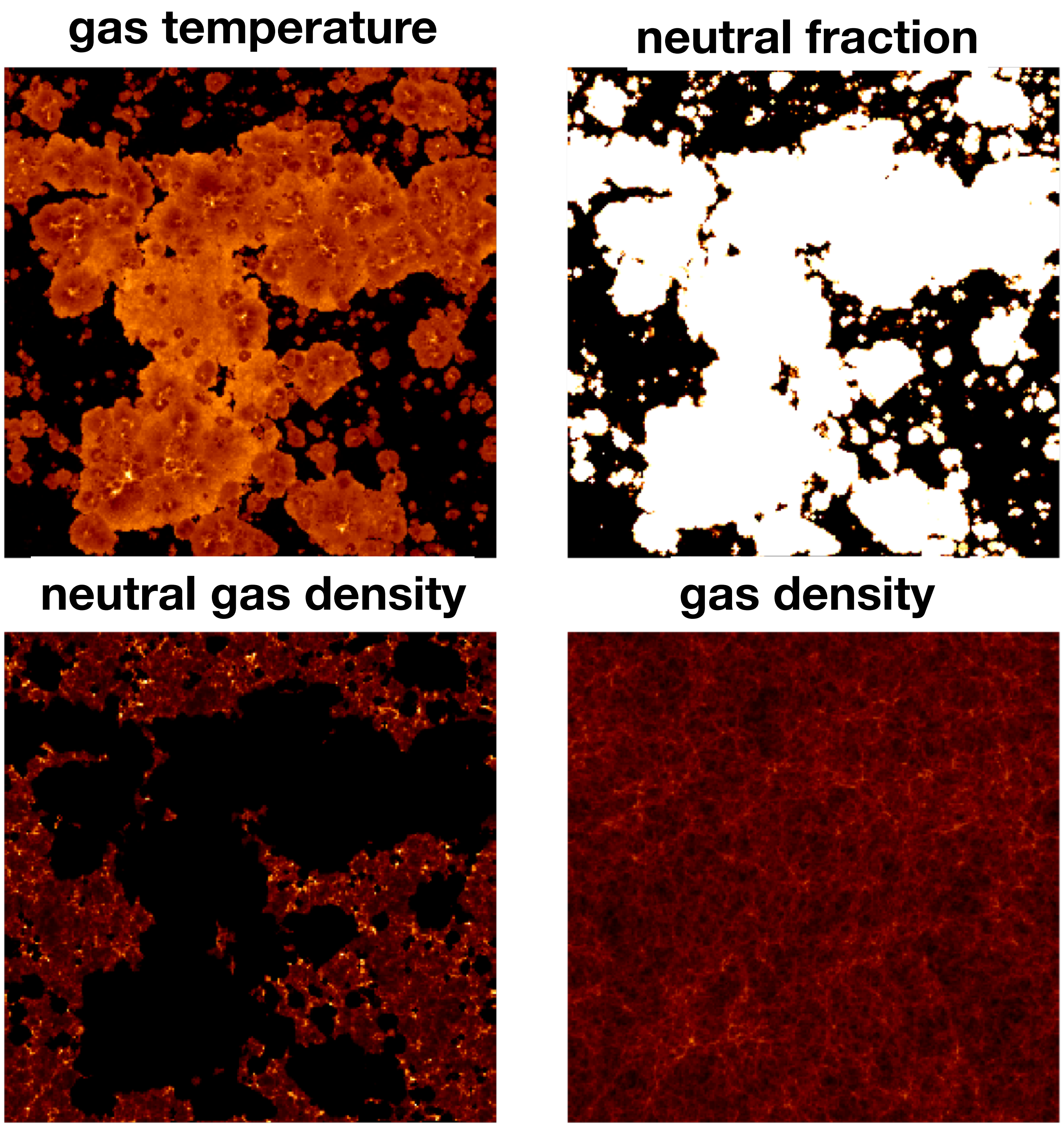
What can we know with multiple lines?

CLOUDY output
with -3 < logU < -1





[OIII]輝線と21cm線の空間分布



- 流体シミュレーション MBII

$100h^{-1}$ cMpc
$m_{DM} = 1.1 \times 10^{7} h^{-1} M_{\odot}$
$m_{gas} = 2.2 \times 10^{6} h^{-1} M_{\odot}$

- 輻射輸送計算
（ポストプロセス）

Eide+ 2018
グリッド数： 256^3
電離源：

- Stars
- X-ray binaries
- Thermal bremsstrahlung
- Accreting nuclear BHs

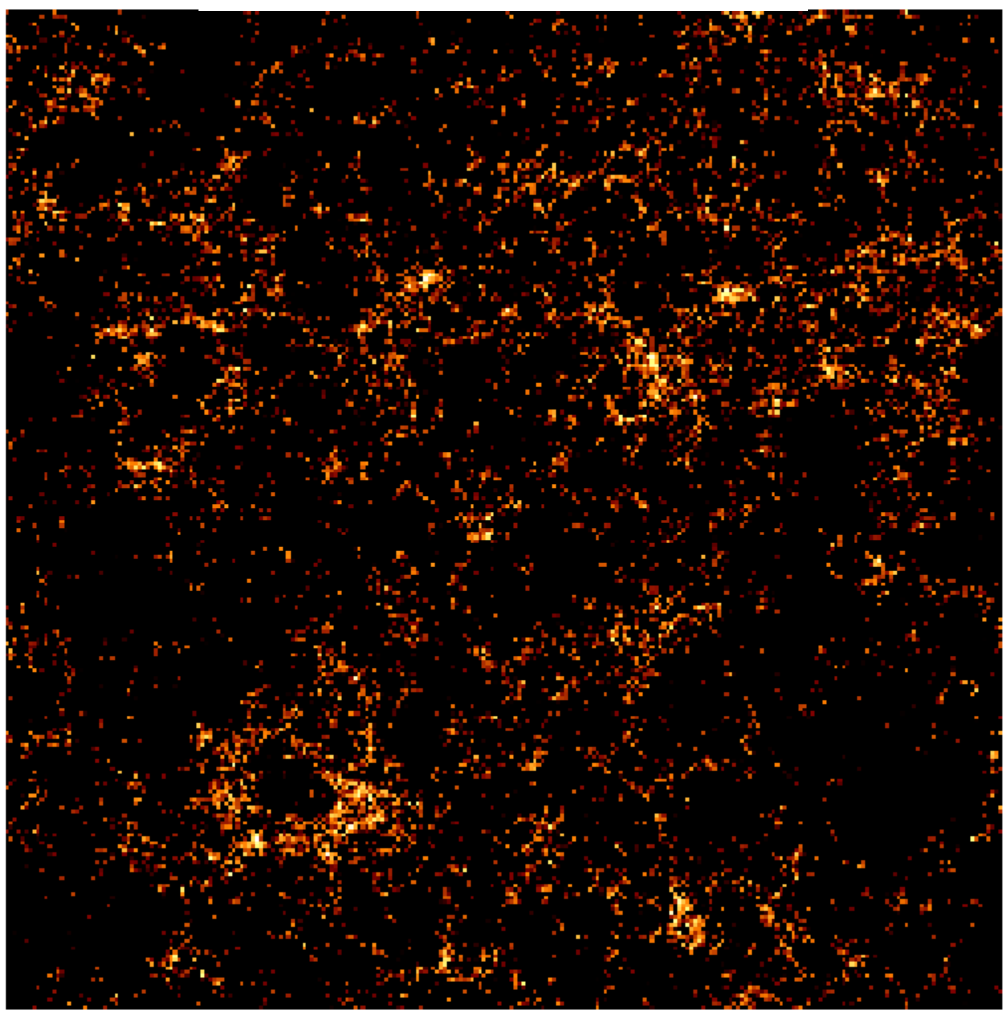
$f_{esc} = 0.15$（固定）

[OIII]輝線と21cm線の空間分布

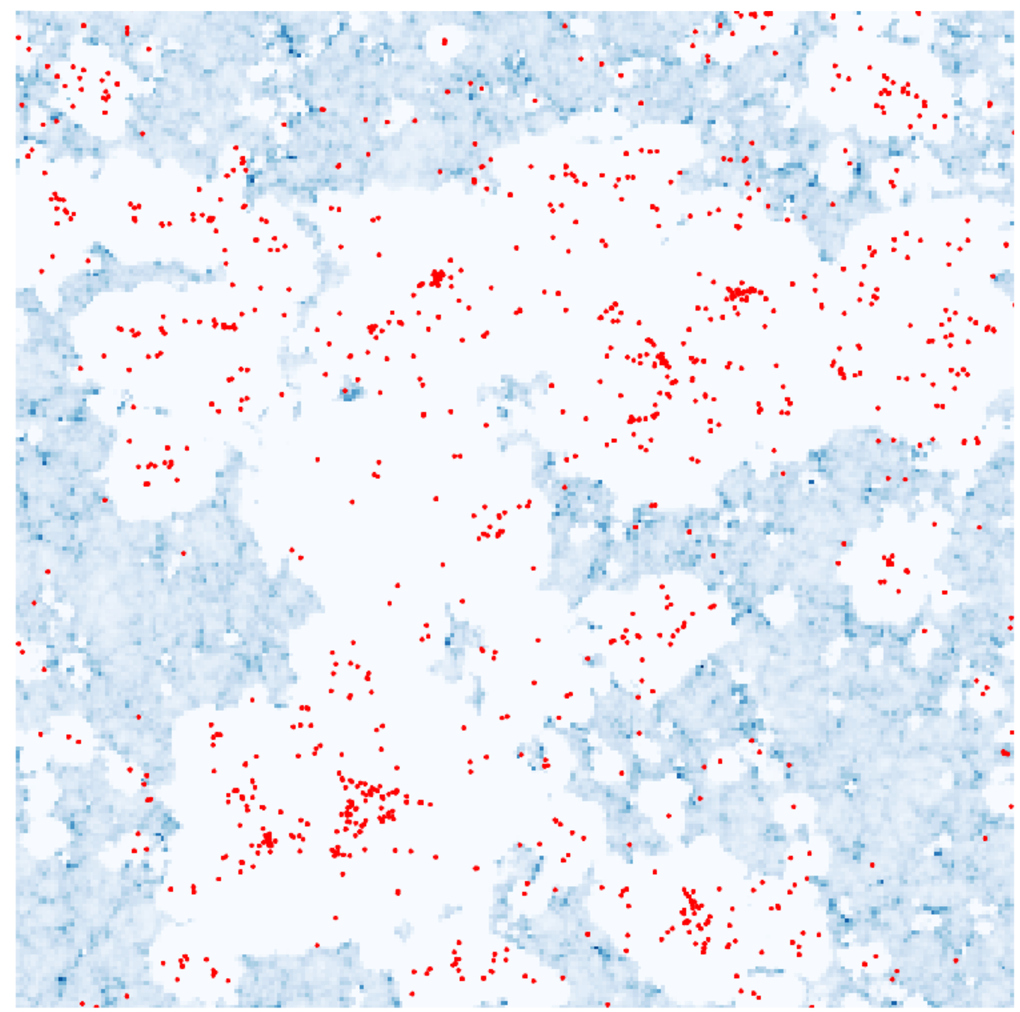
輝線： $L_{\rm line} = (1 - f_{\rm esc}) \times C(Z, n, U) \times L^{\rm caseB}_{\rm H\beta}(Z^*, t^*, M^*)$

21cm線： $\delta T_{21}(\boldsymbol{r}) = T_0 \left\langle x_{\rm HI} \right\rangle \left(\frac{T_s(\boldsymbol{r}) - T_{\rm CMB}}{T_s(\boldsymbol{r})} \right) (1 + \delta_\rho(\boldsymbol{r}))(1 + \delta_x(\boldsymbol{r}))$

[OIII] 5007 intensity



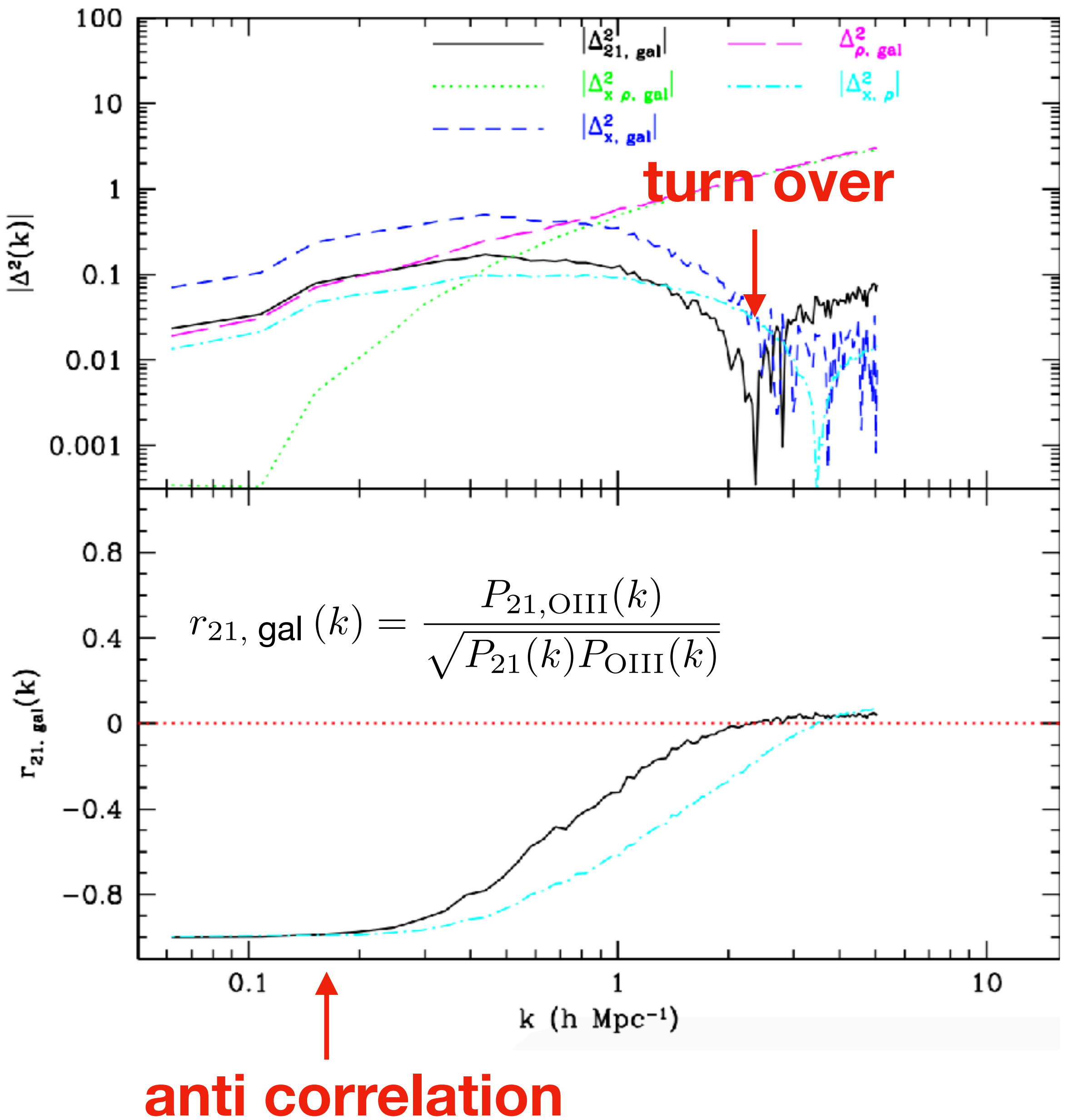
$n_{\rm HI}$ (color) + galaxies

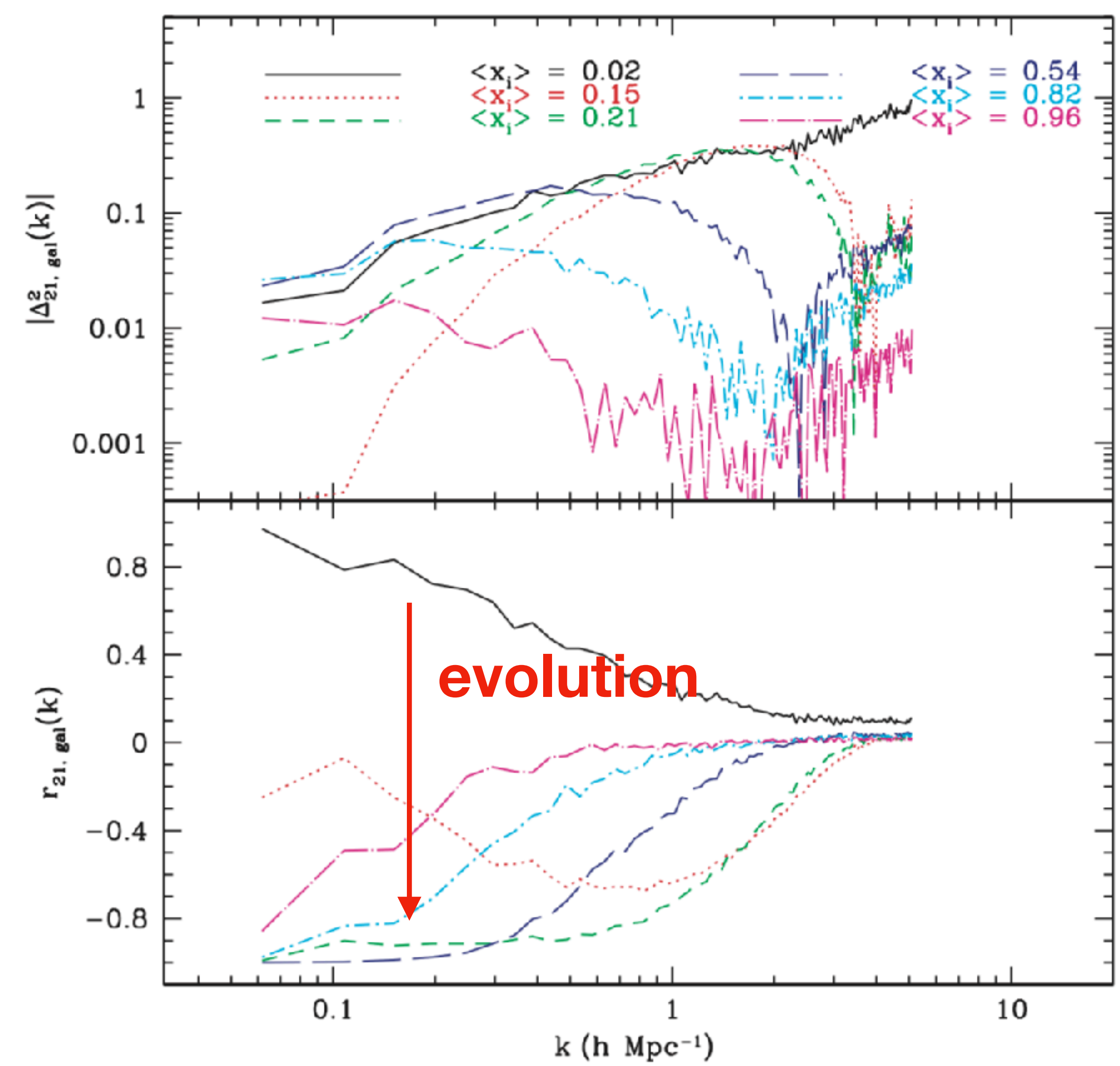


[OIII] の観測方法：① サーベイ（→[OIII]銀河個数密度）、② intensity mapping

[OIII]輝線と21cm線の空間分布

LAE との相関 e.g. Lidz+ 2009





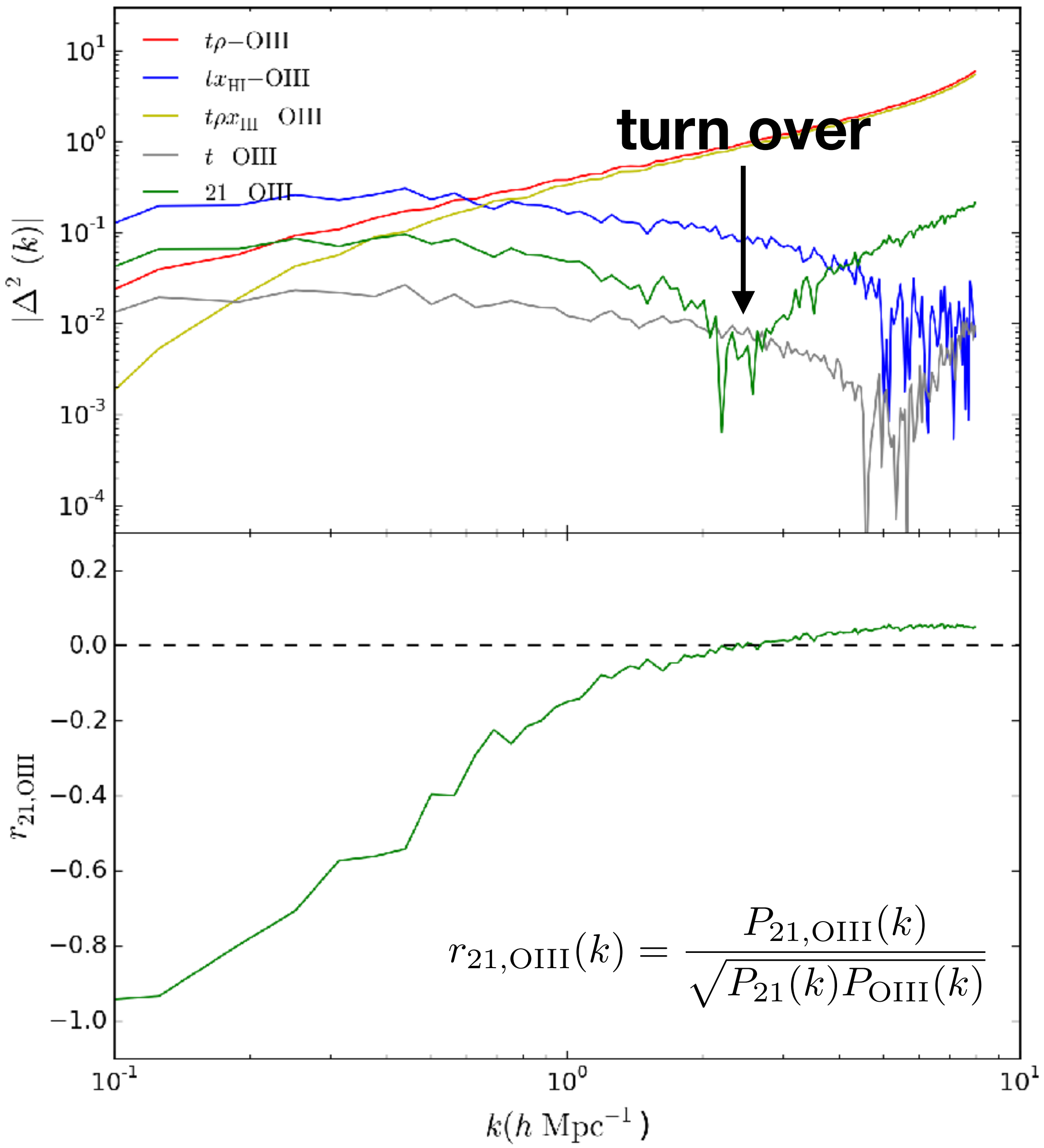
[OIII]輝線と21cm線の空間分布

$$\Delta^2_{21,\mathrm{OIII}}(k) = \frac{k^3}{2\pi^2} P_{21,\mathrm{OIII}}(k)$$
$$= \langle \chi_{\mathrm{HI}} \rangle \left[\Delta^2_{\chi,\mathrm{OIII}}(k) + \Delta^2_{\rho,\mathrm{OIII}}(k) + \Delta^2_{\chi\rho,\mathrm{OIII}}(k) \right]$$

z = 7.5

21 vs [OIII] number density

$L_{[\mathrm{OIII}]5007} > 10^{36}$ erg/s



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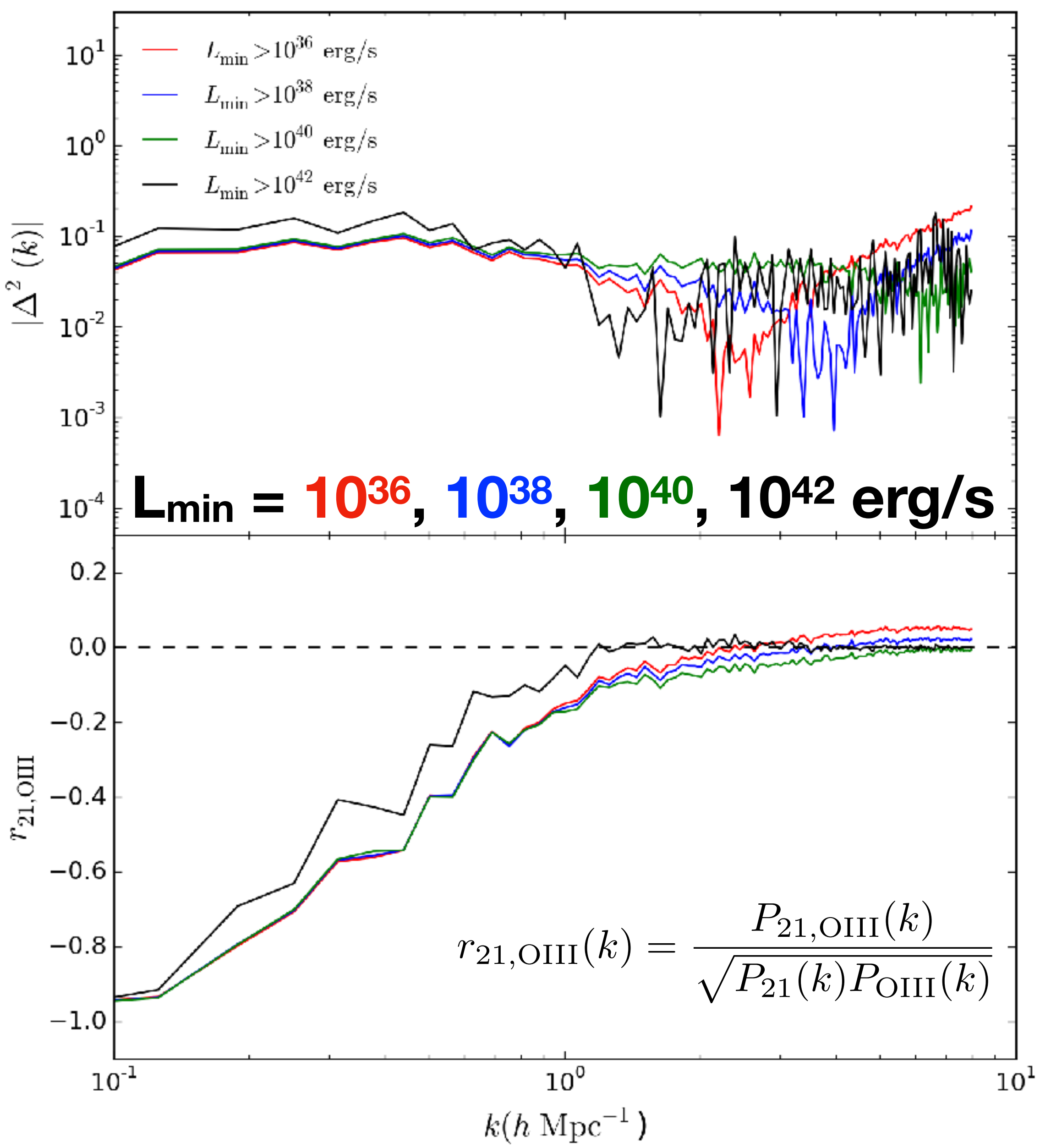

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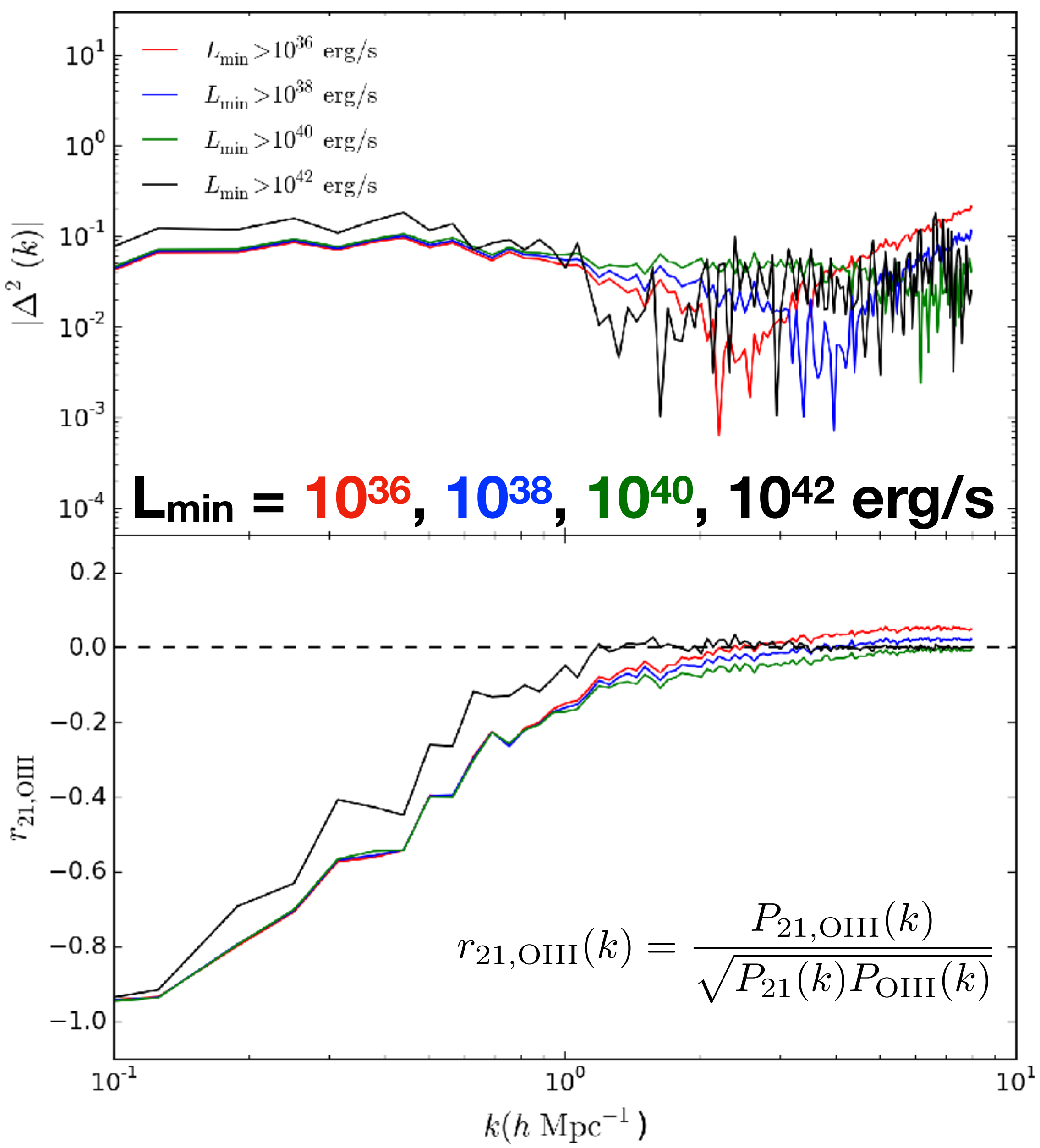
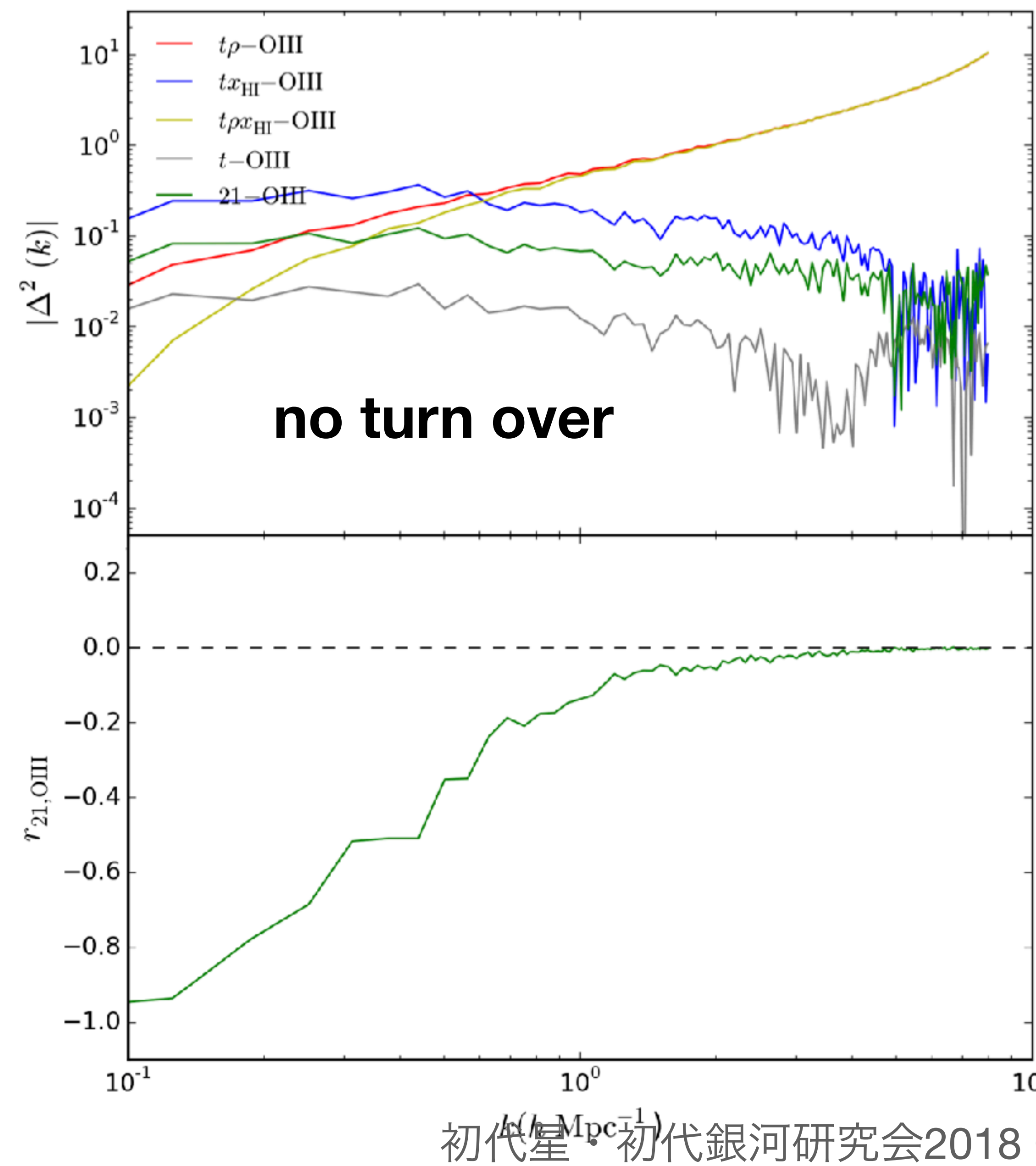


21 vs luminosity density



まとめ

- **HII領域モデルを宇宙論シミュレーションに適応して z > 7 における [OIII]輝線銀河の振る舞いをしらべた**

  - 0.1” 以下の各分解能で、個々の星形成領域を分解できる

  - JWST を用いて z ~ 8 の [OIII] 5007 銀河の分布を調べられる

  - [OIII] 88μm/52μm/5007Å 輝線強度比を用いると密度だけでなく金属量も推定できる

- **21cm線と[OIII]輝線銀河の相互パワースペクトルを調べた**

  - 個数密度と光度密度を使う場合で振る舞いが異なる