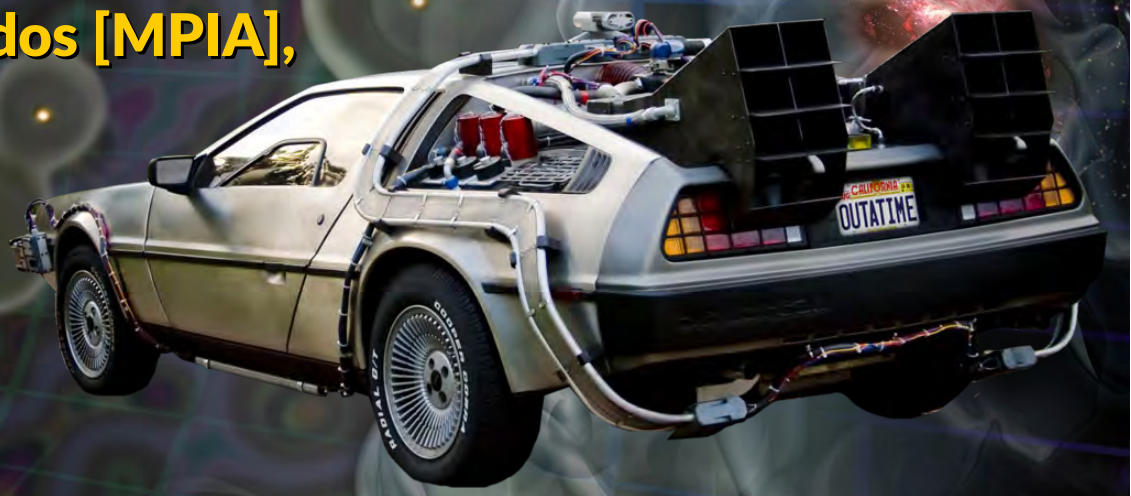
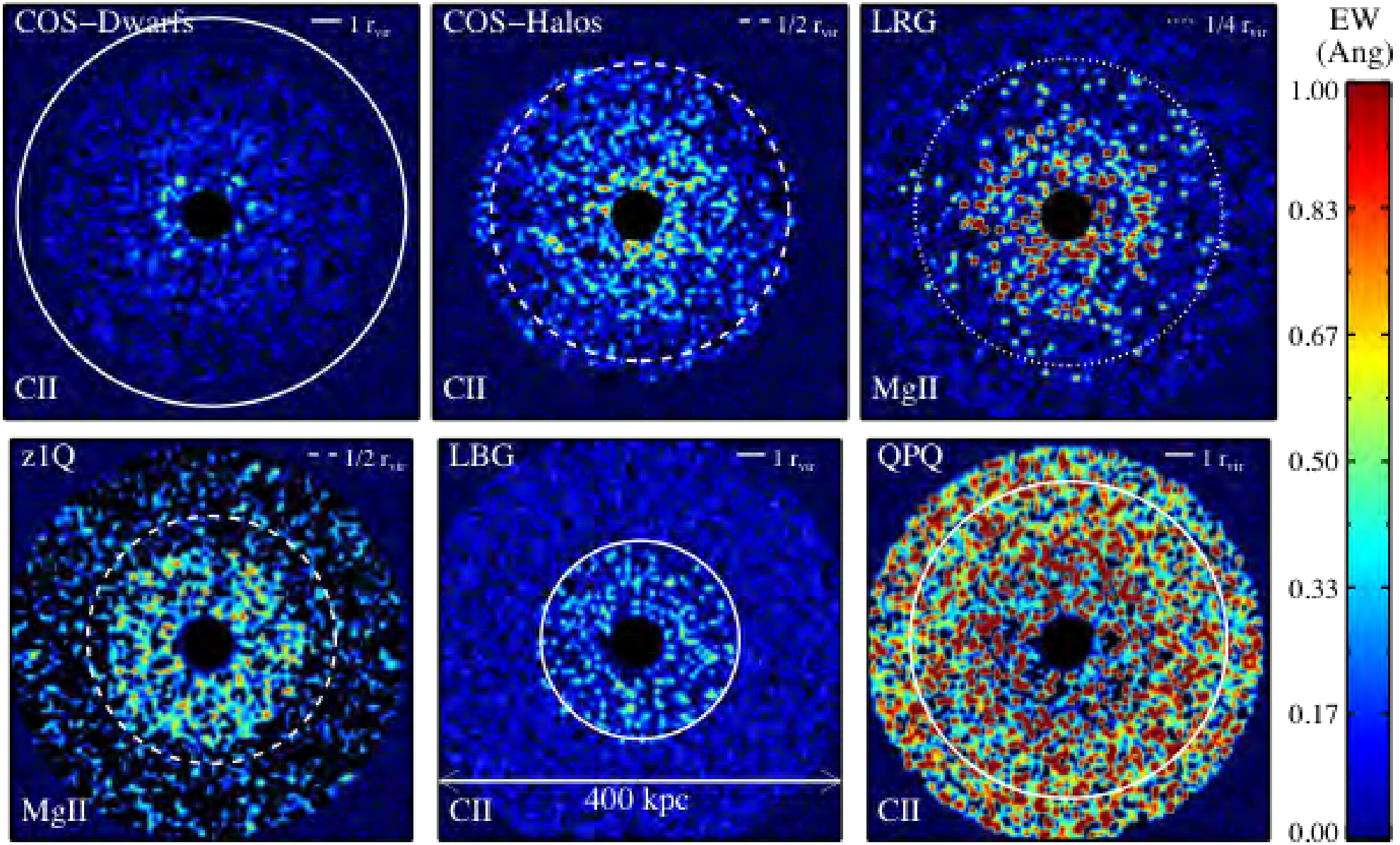
from Dawn till Noon:
(non-)Evolution of the CGM in the first 3Gyr of Cosmic time

Emanuele (Ema) Farina
MPIA/MPA/???

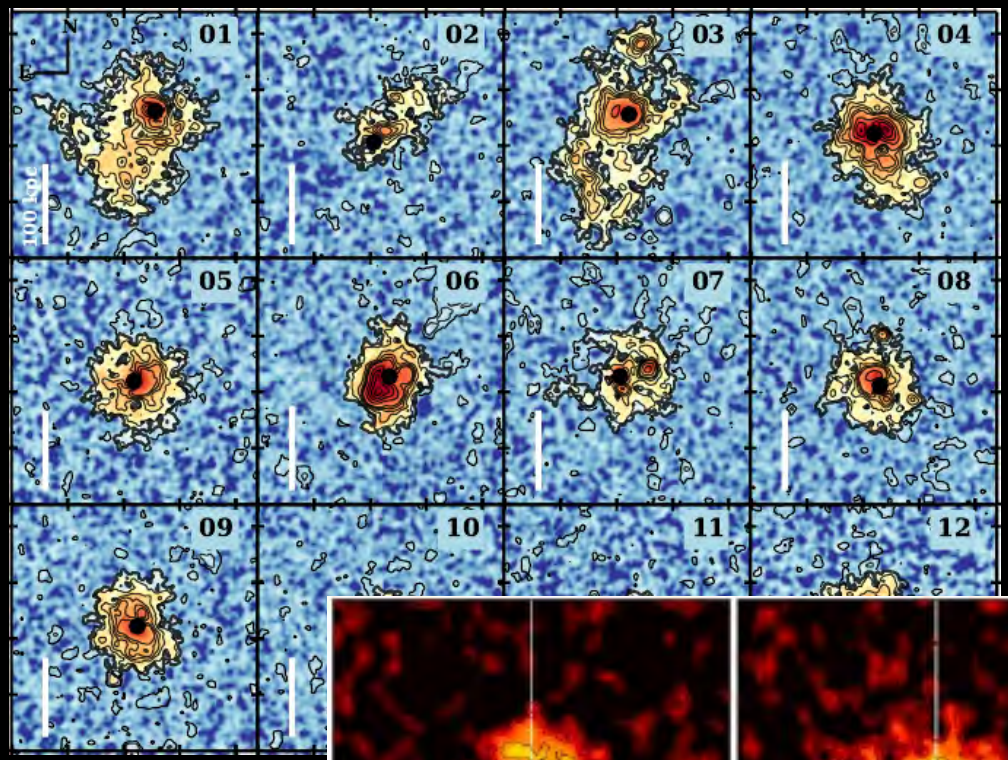
Arrigoni-Battaia [MPA], Costa [MPA]

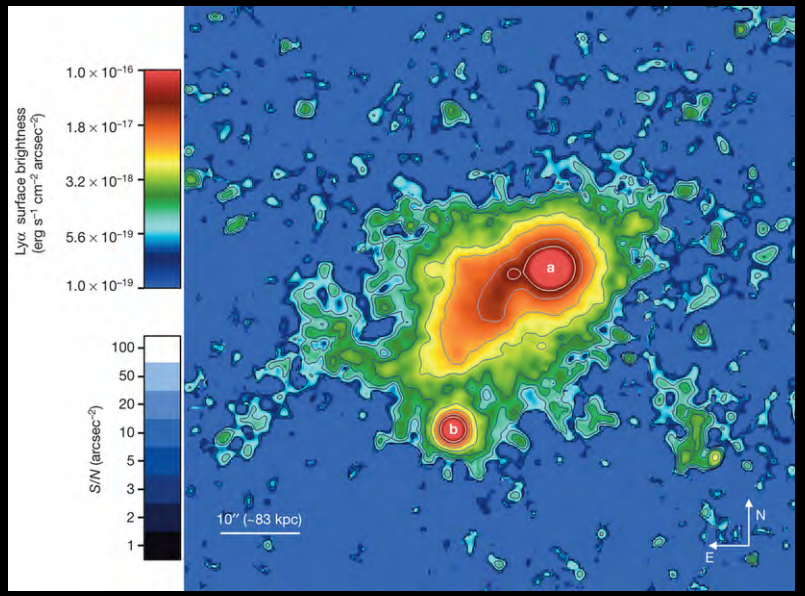
Walter [MPIA], Hennawi [UCSB], Drake [MPIA], Decarli [INAF], Gutcke [MPA], Mazzucchelli [ESO], Neeleman [MPIA], Eilers [MPIA], Davies [UCSB], Bañados [MPIA], Fan [Steward], Venemans [MPIA], Schindler [MPIA], Wang [UCSB], Yang [Steward], Onoue [MPIA], and many others..

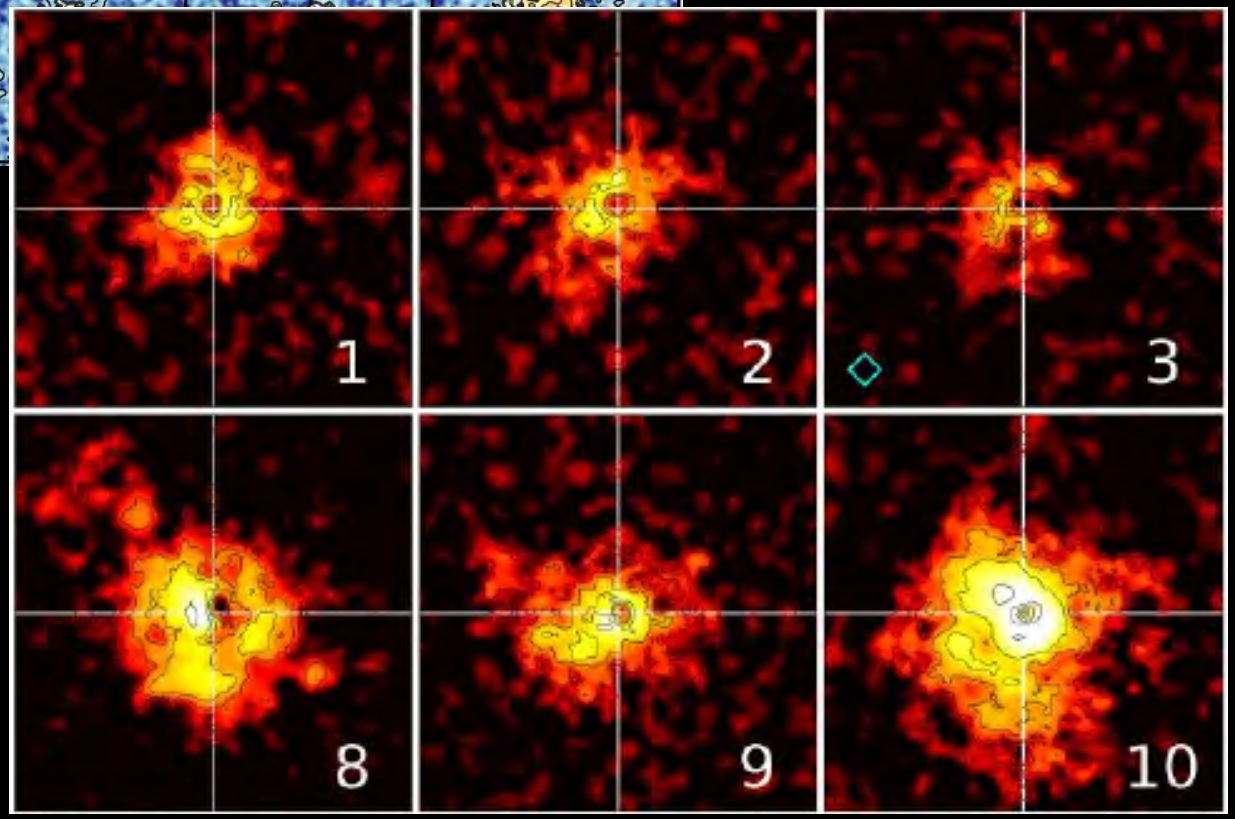




QSOs: Bowen et al., Farina et al., Hennawi et al., Johnson et al., Prochaska et al., ...
Galaxies: Chen et al., Bahcall et al., Werk et al., Nielsen et al., Kacprzak et al., Churchill et al., Tumlinson et al., Martin et al., and **MANY** more







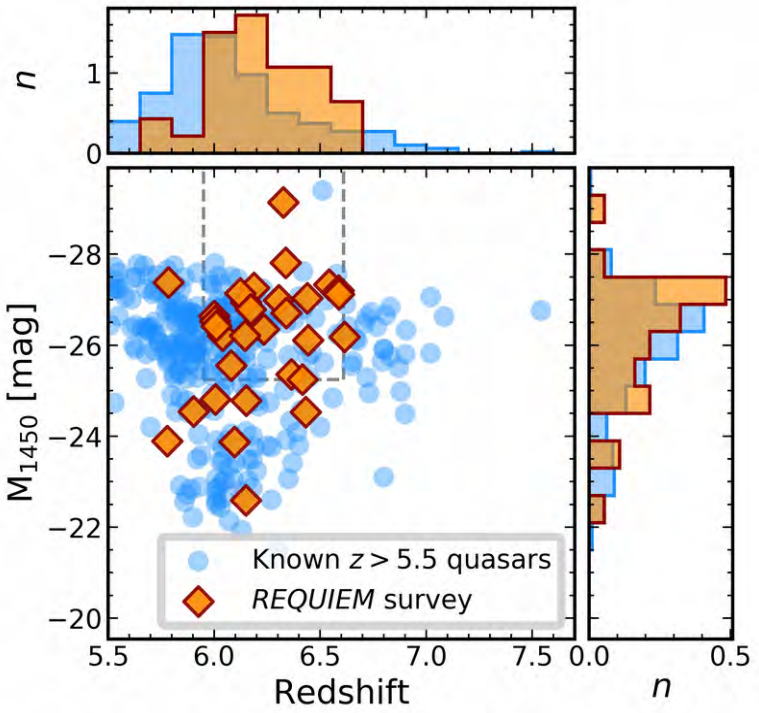
Cantalupo et al. 2014, Borisova et al. 2016 , Arrigoni–Battaia et al. 2019

the 

survey

Reionization Epoch Quasar InvEstigation with Muse

the *REQUIEM* survey

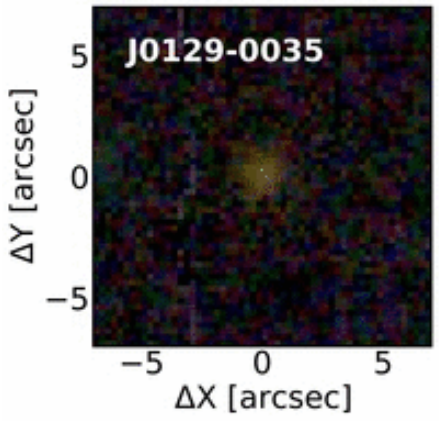


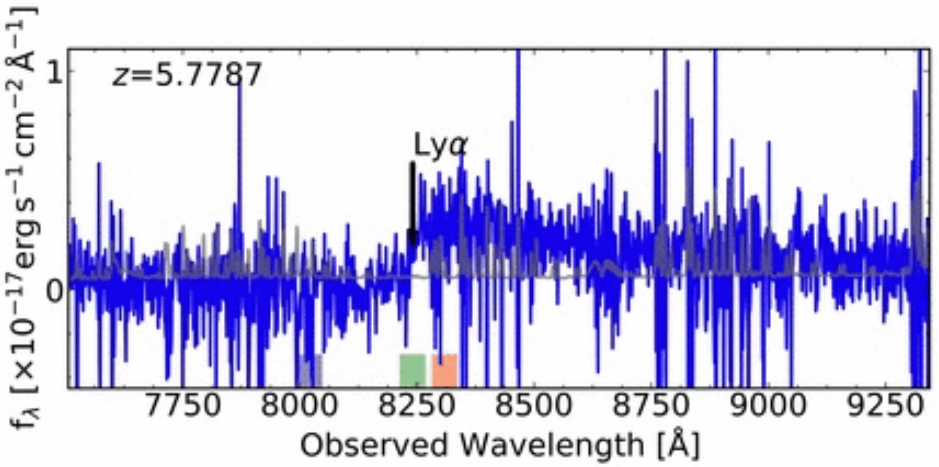
31 QSOs ..more to come..

SB_{lim}~0.1-1x10^{-17}erg/s/cm^2/arcsec^2

<z>=6.22

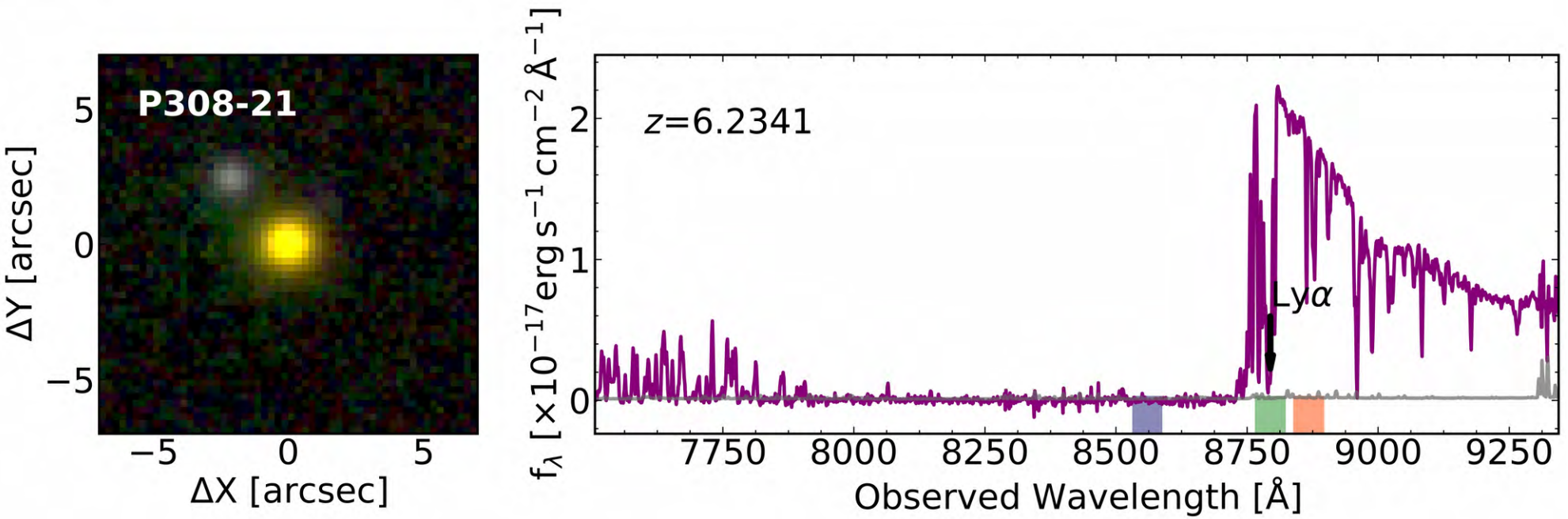
<M_{1450}>=-26.85mag





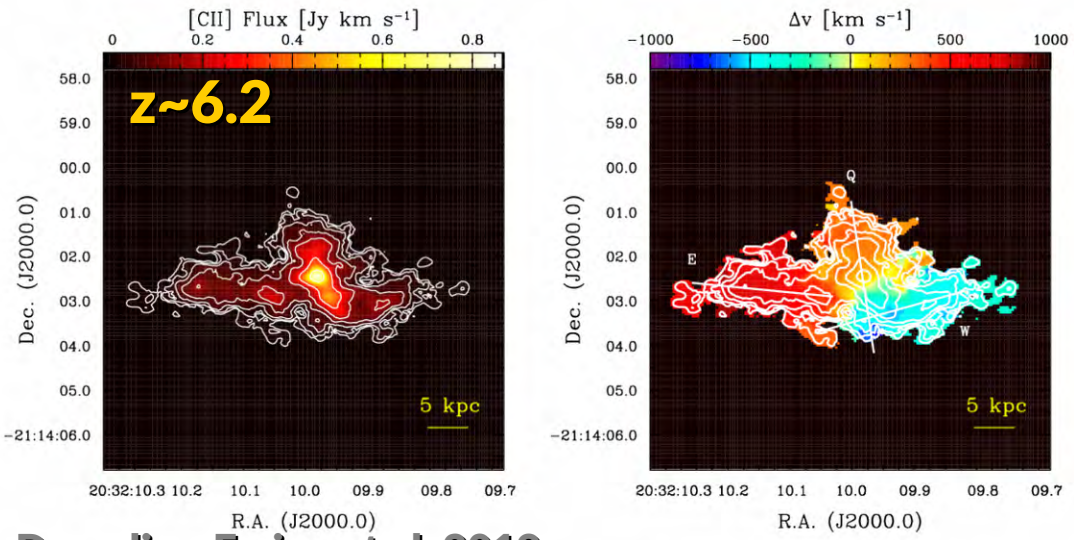
the *REQUIEM* survey

z~6.2

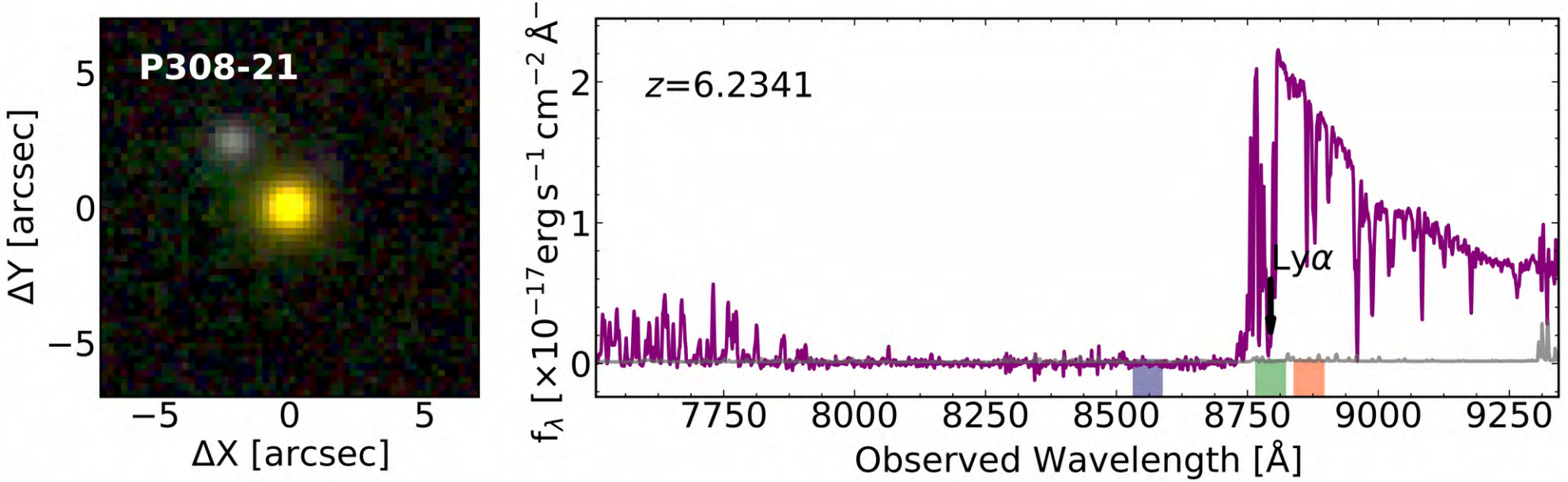


Farina et al. 2019 subm.

the *REQUIEM* survey

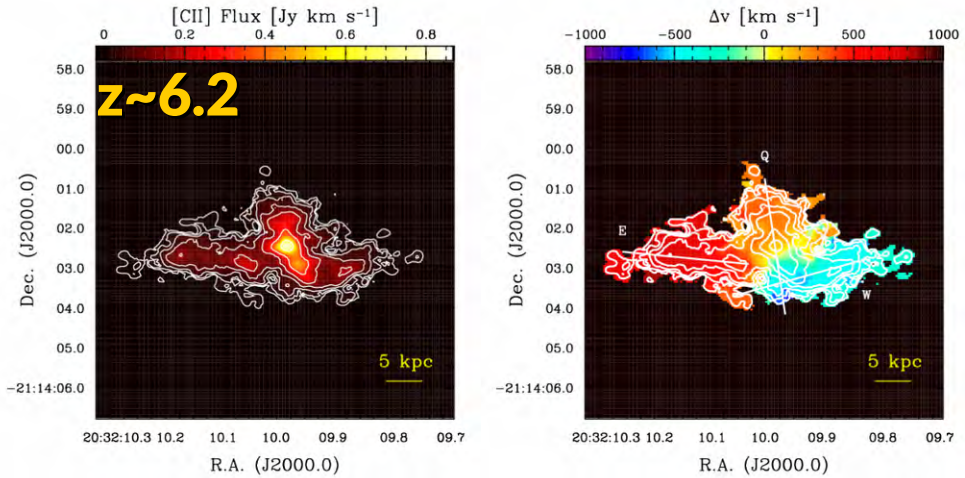


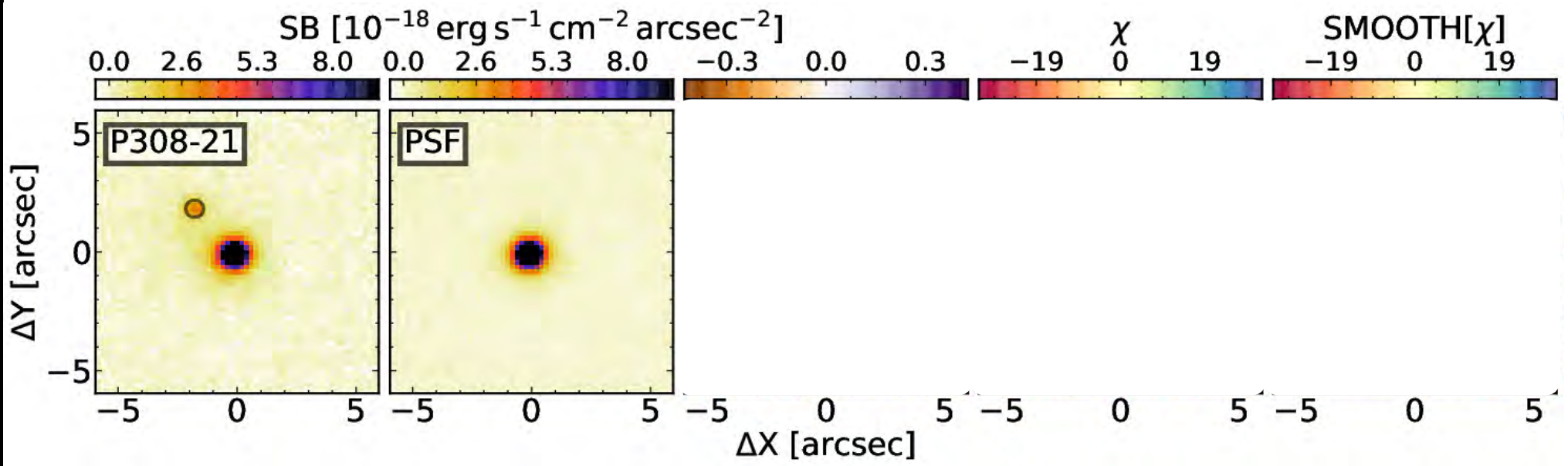
Decarli, .., Farina et al. 2019.



Farina et al. 2019 subm.

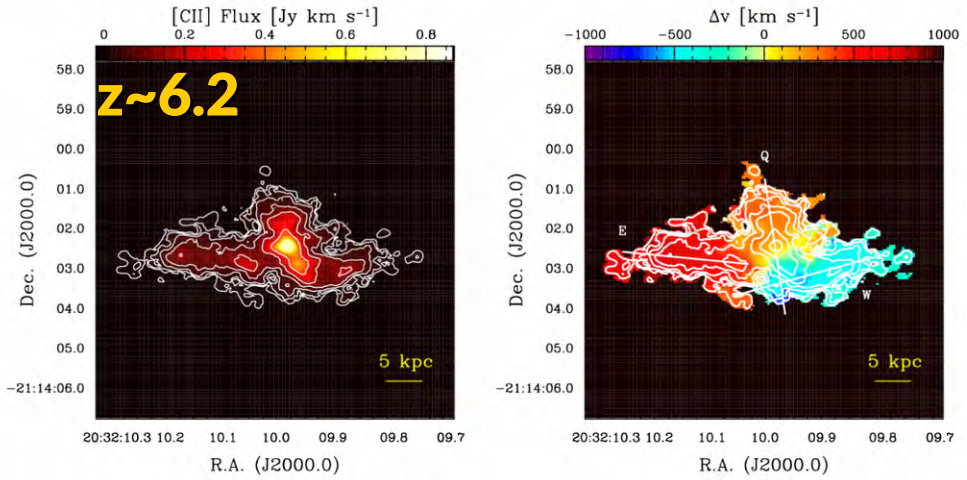
the *REQUIEM* survey



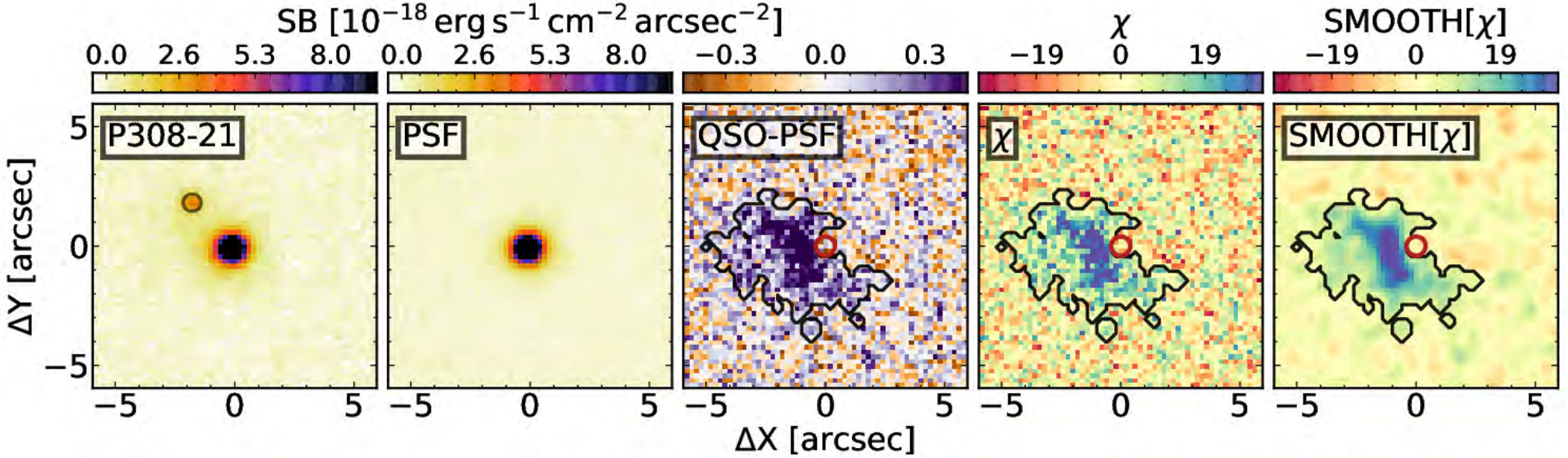


Farina et al. 2019 subm.

the *REQUIEM* survey

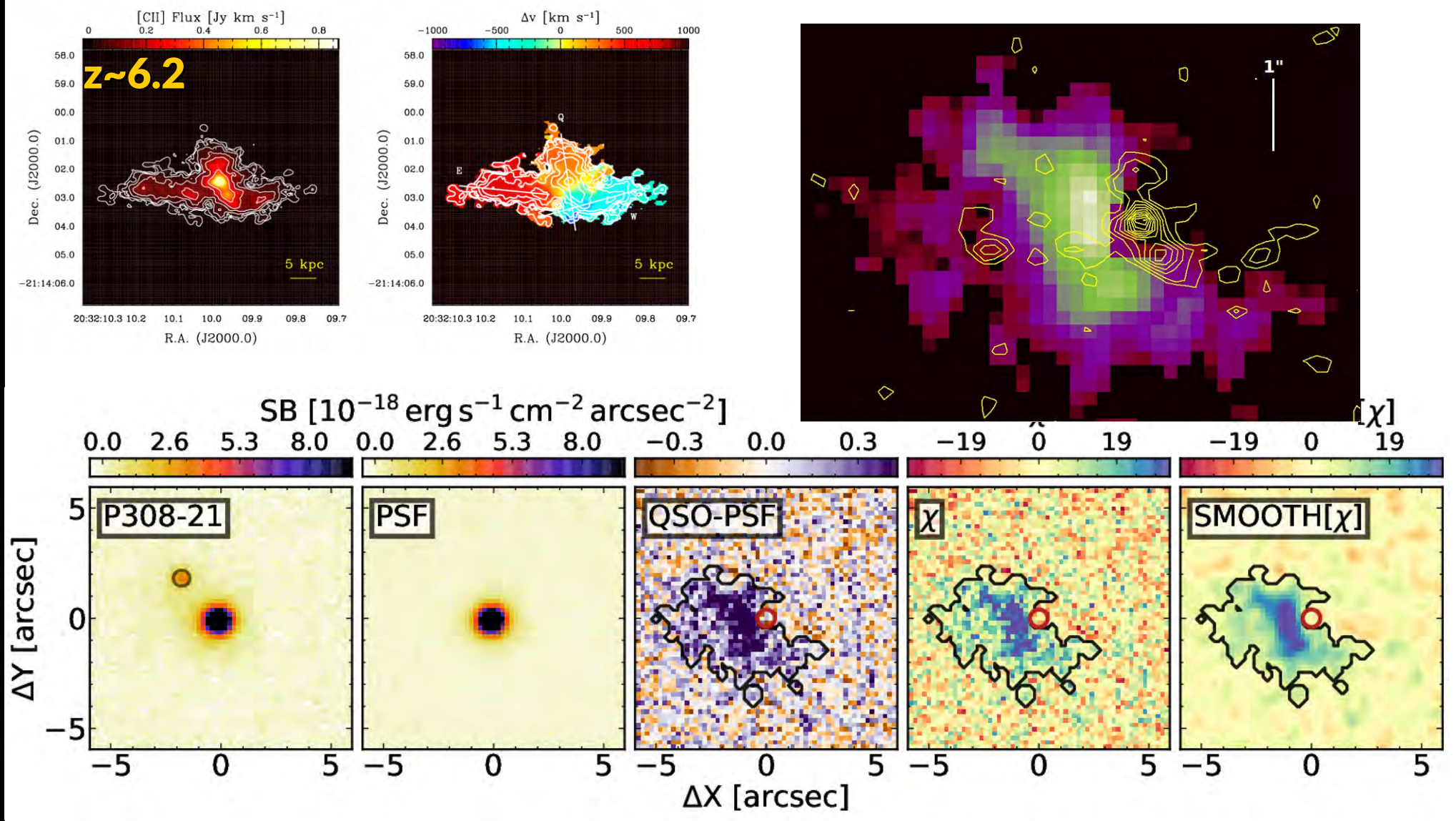


~43kpc Lyα Nebula
L(Lyα)=9x10^{43}erg/s



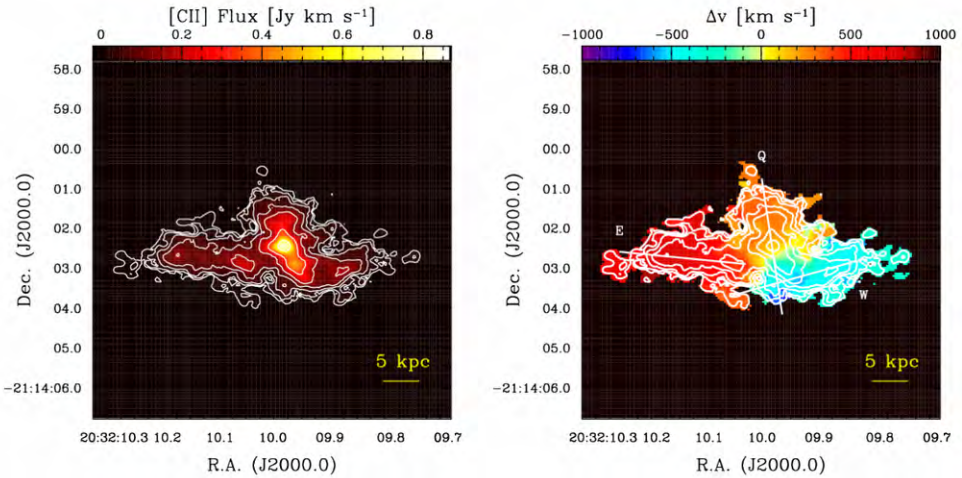
Farina et al. 2019 subm.

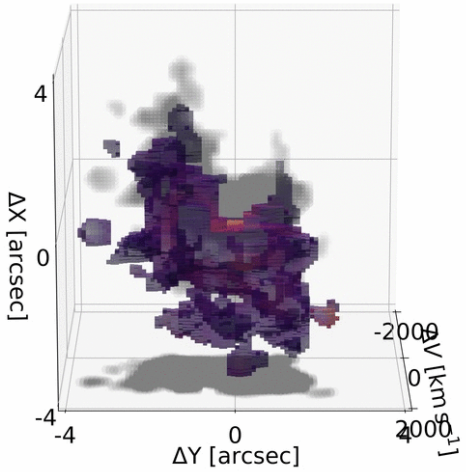
the *REQUIEM* survey

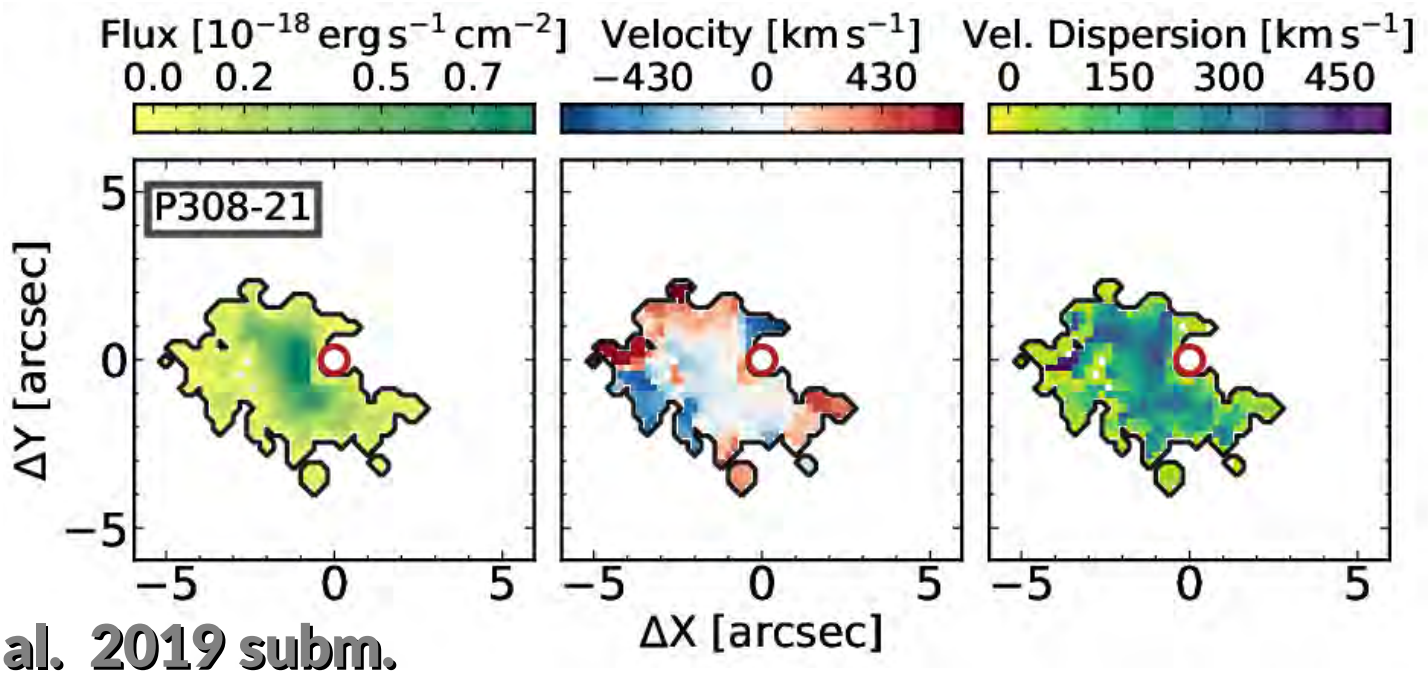


Farina et al. 2019 subm.

a 3D view of the first halos



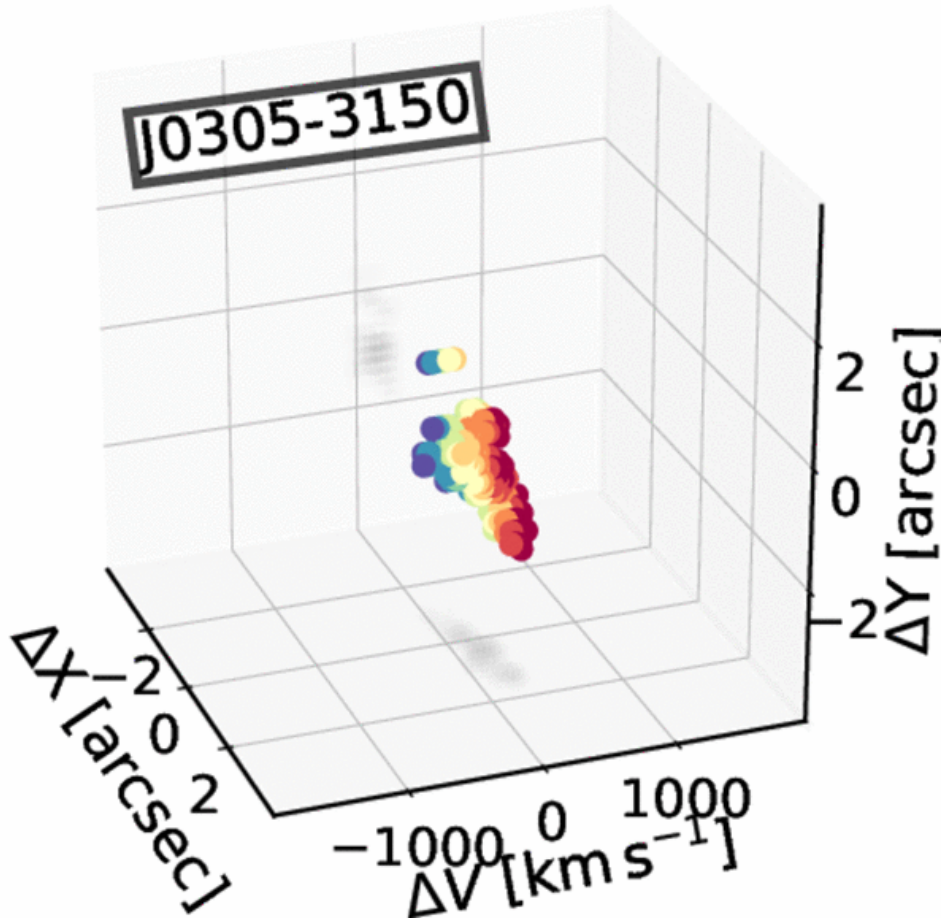




Farina et al. 2019 subm.

a 3D view of the first halos

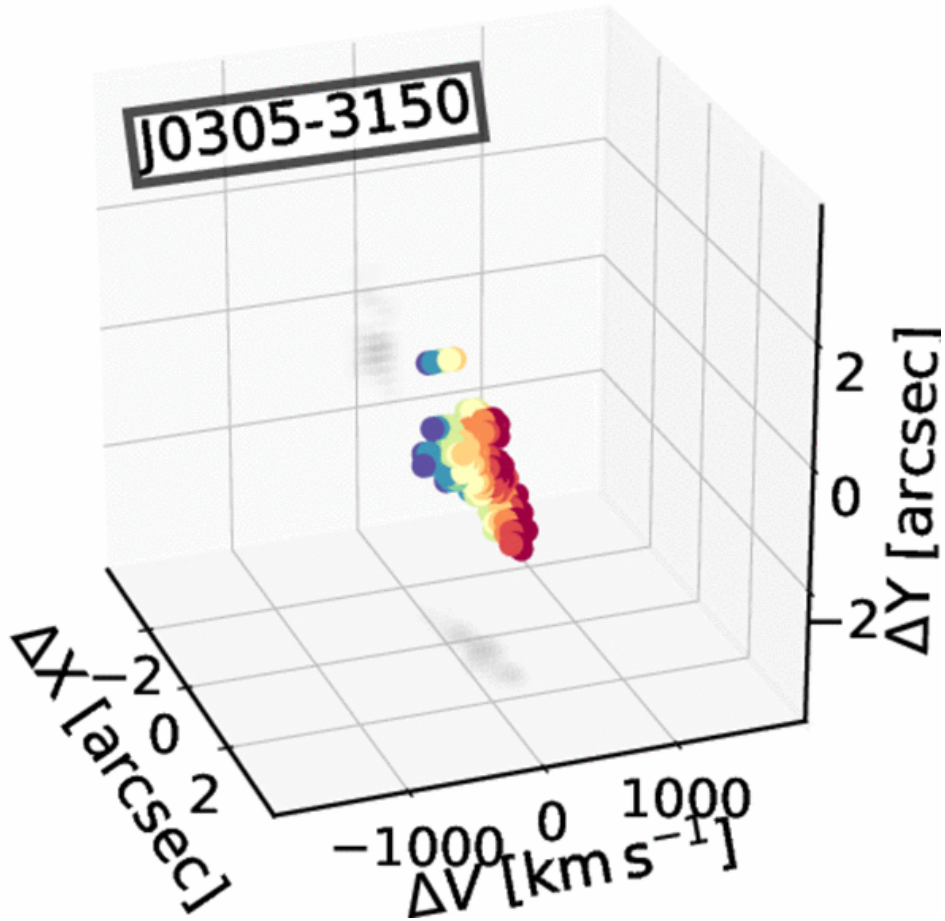
12 halos / 31 targets
[~40%]

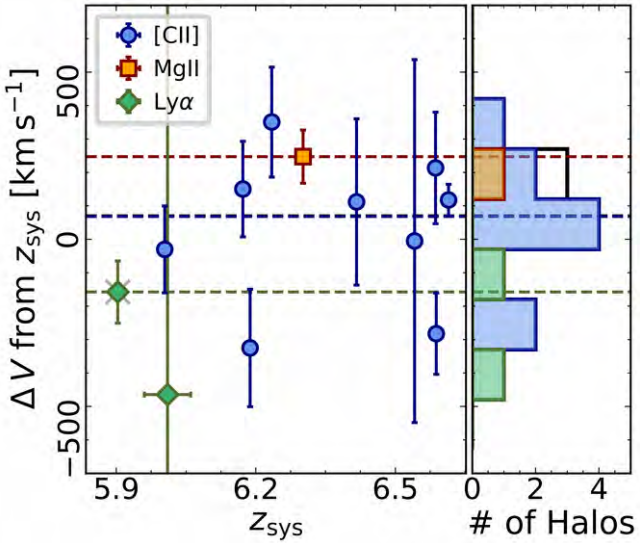


Farina et al. 2019 subm.

a 3D view of the first halos

same redshift wrt the host

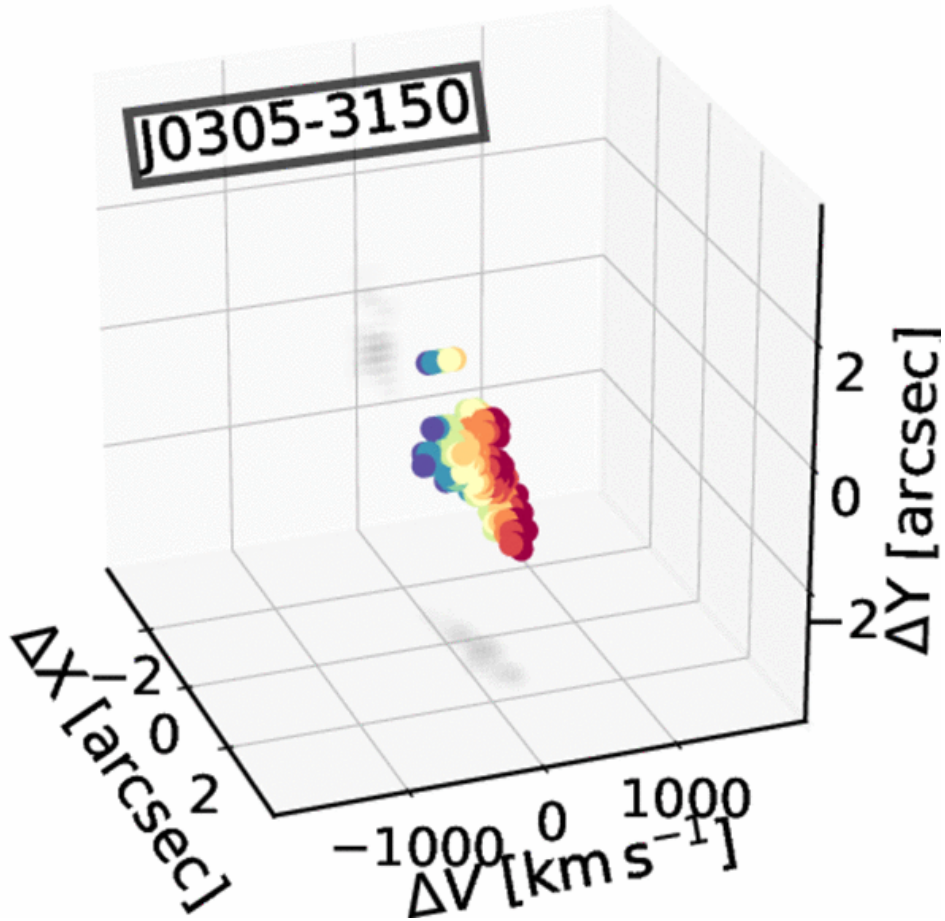


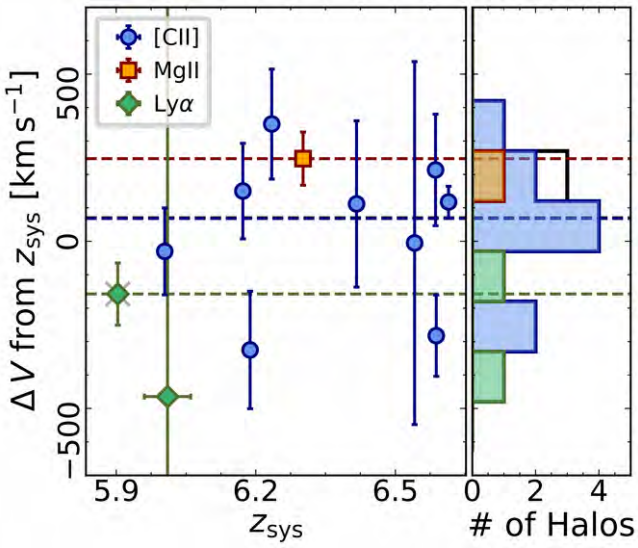


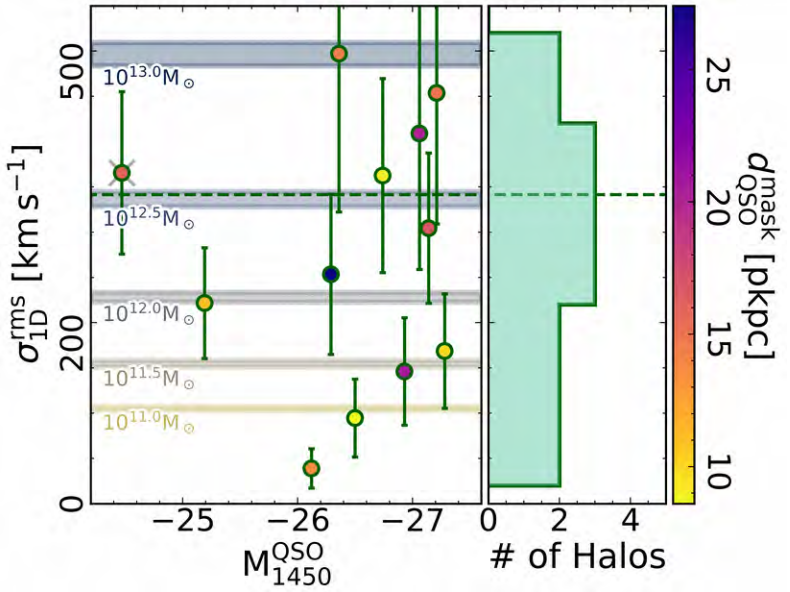
Farina et al. 2019 subm.

a 3D view of the first halos

no extreme kinematics



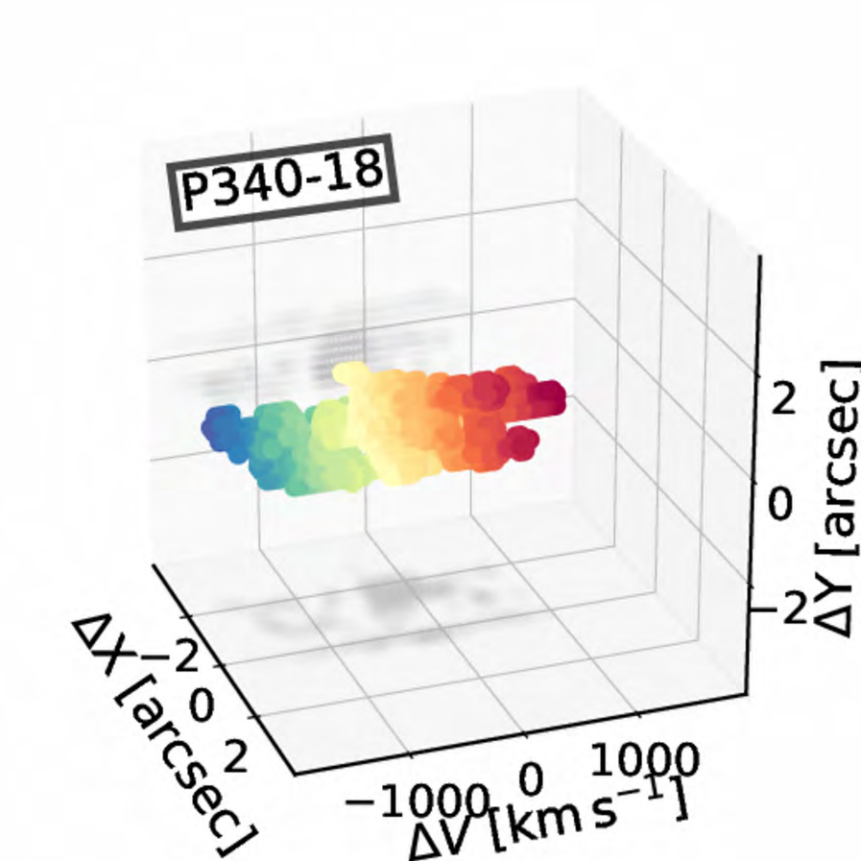


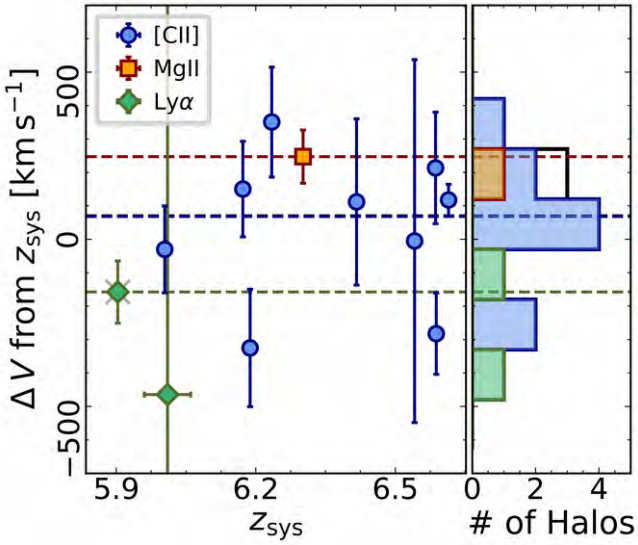


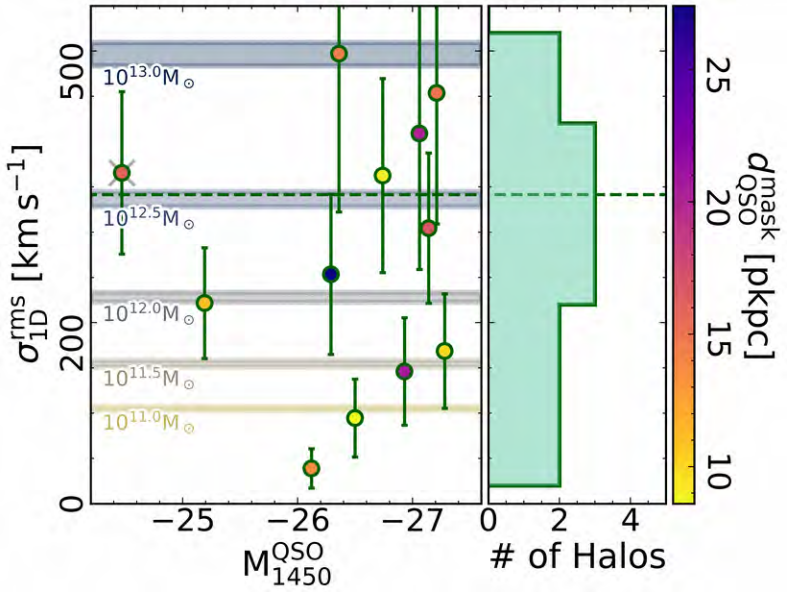
Farina et al. 2019 subm.

a 3D view of the first halos

high velocity dispersion?
[need more data]

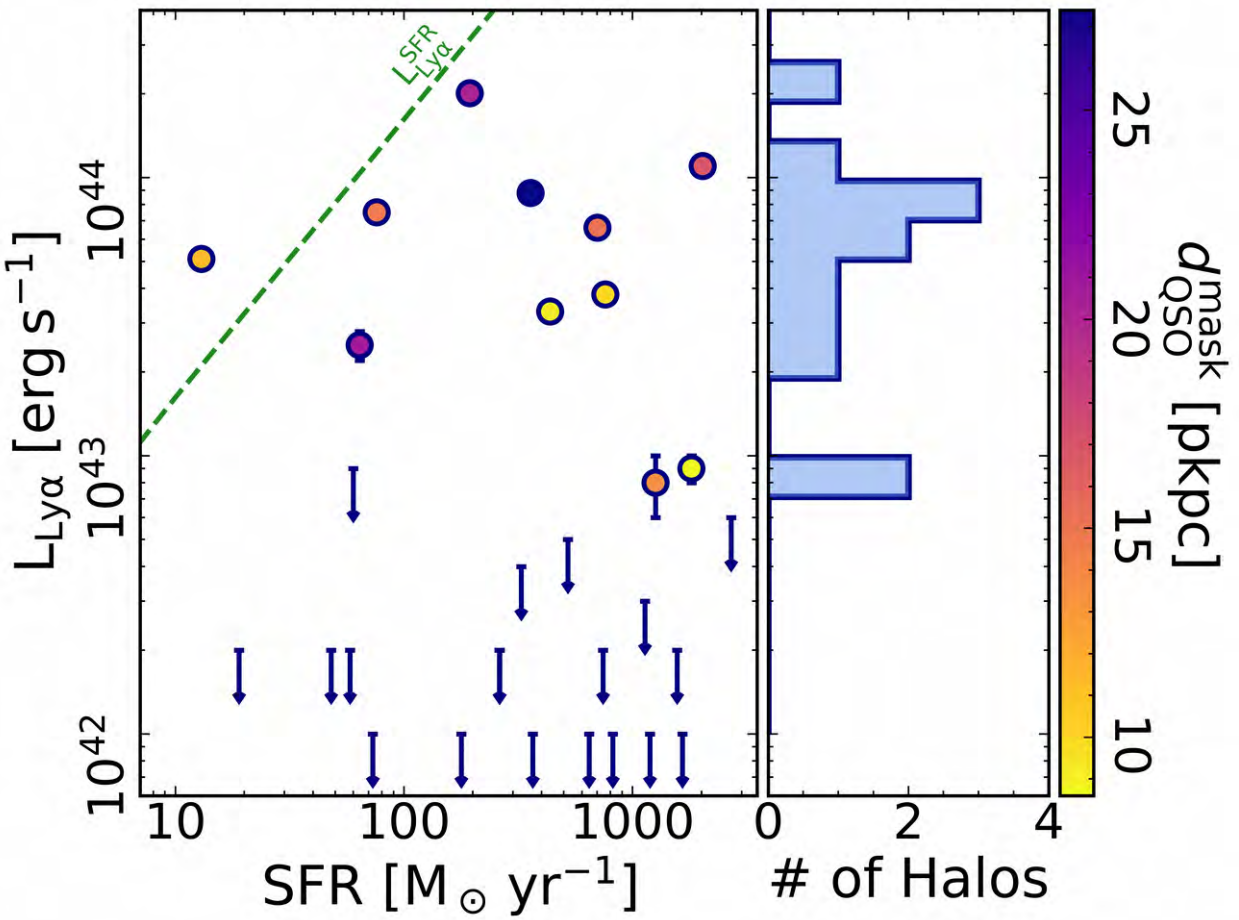






Farina et al. 2019 subm.

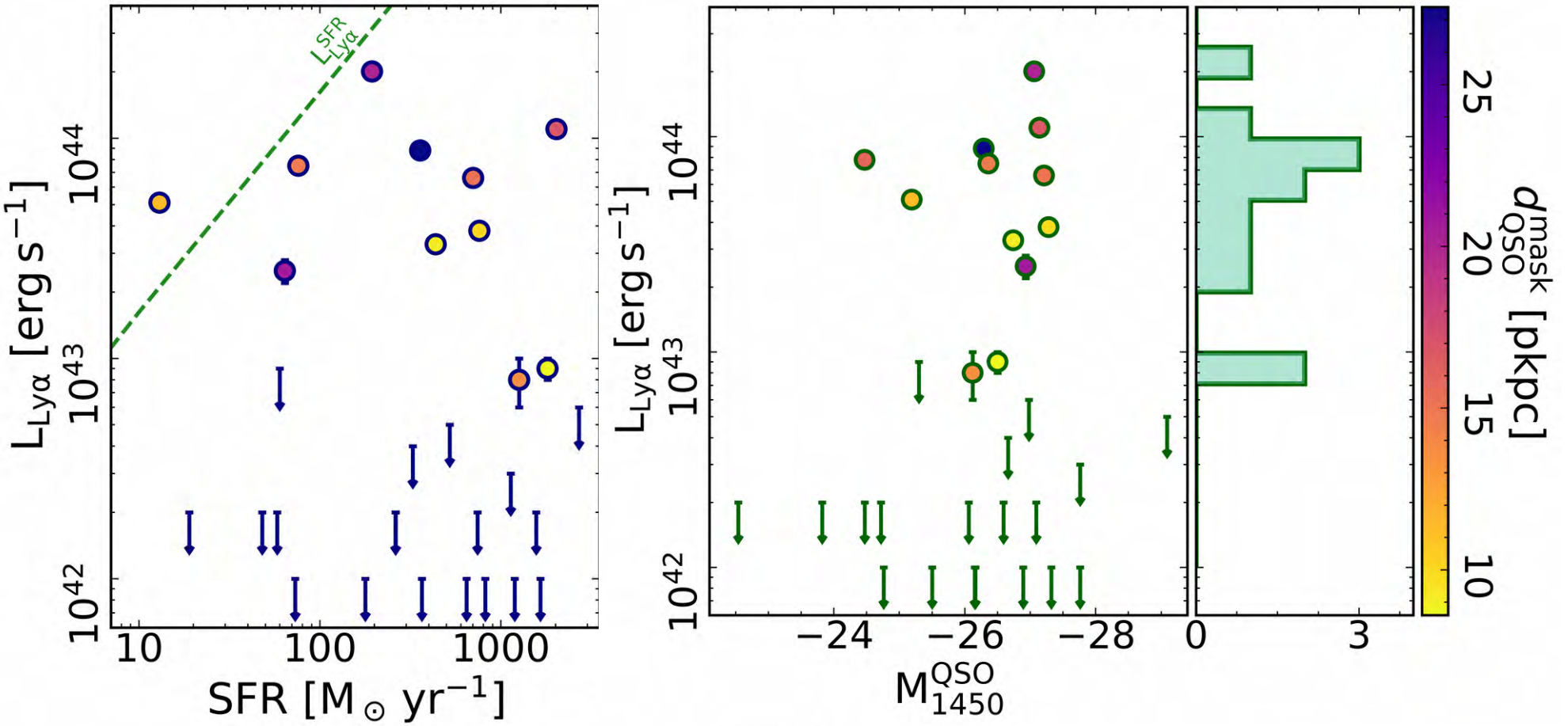
Stars and Accretion Disk Photons



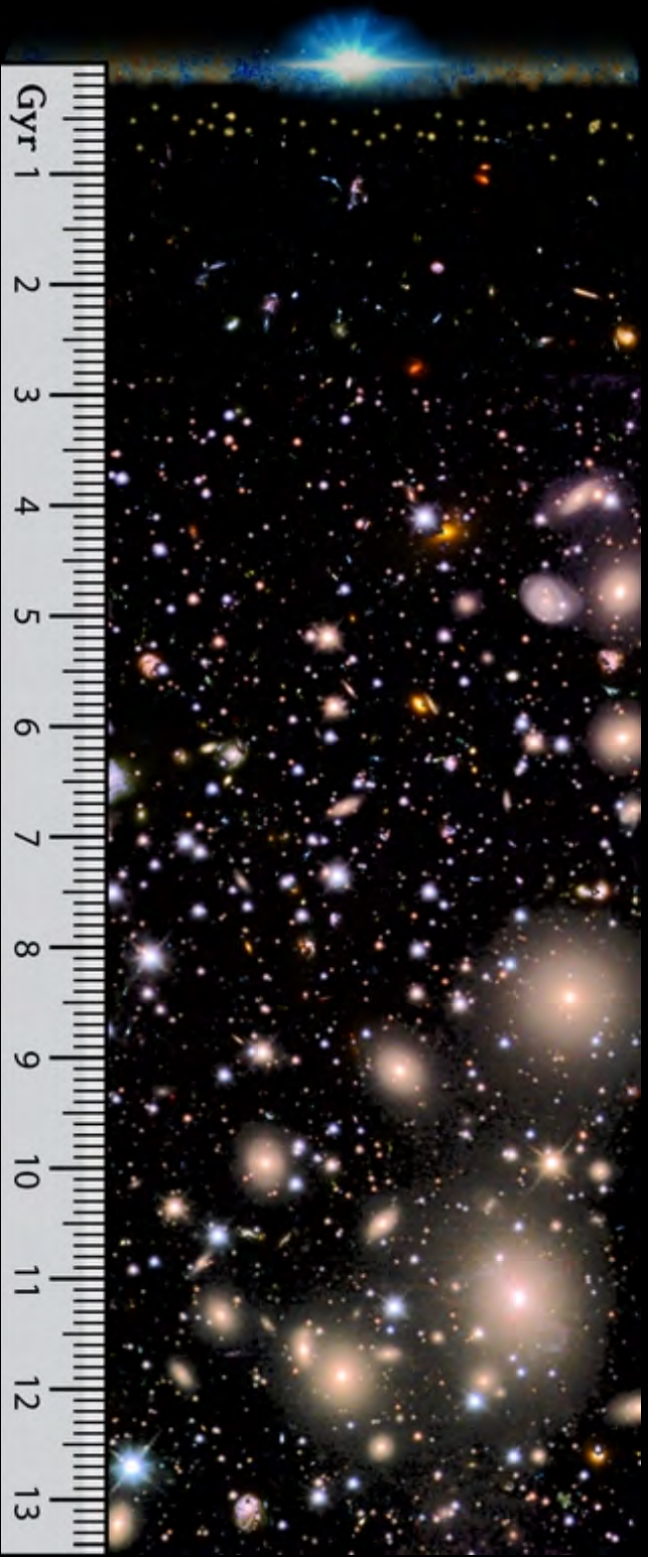
Farina et al. 2019, submitted

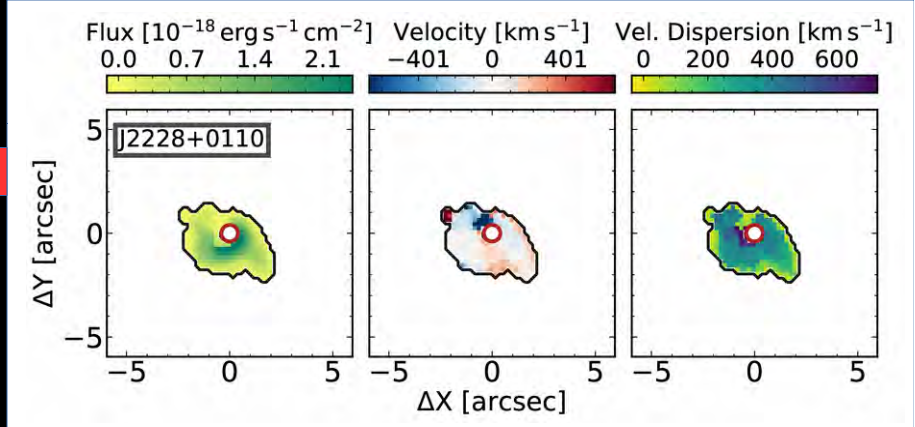
Stars and Accretion Disk Photons

No strong dependency on SFR of the host or magnitude of the quasar

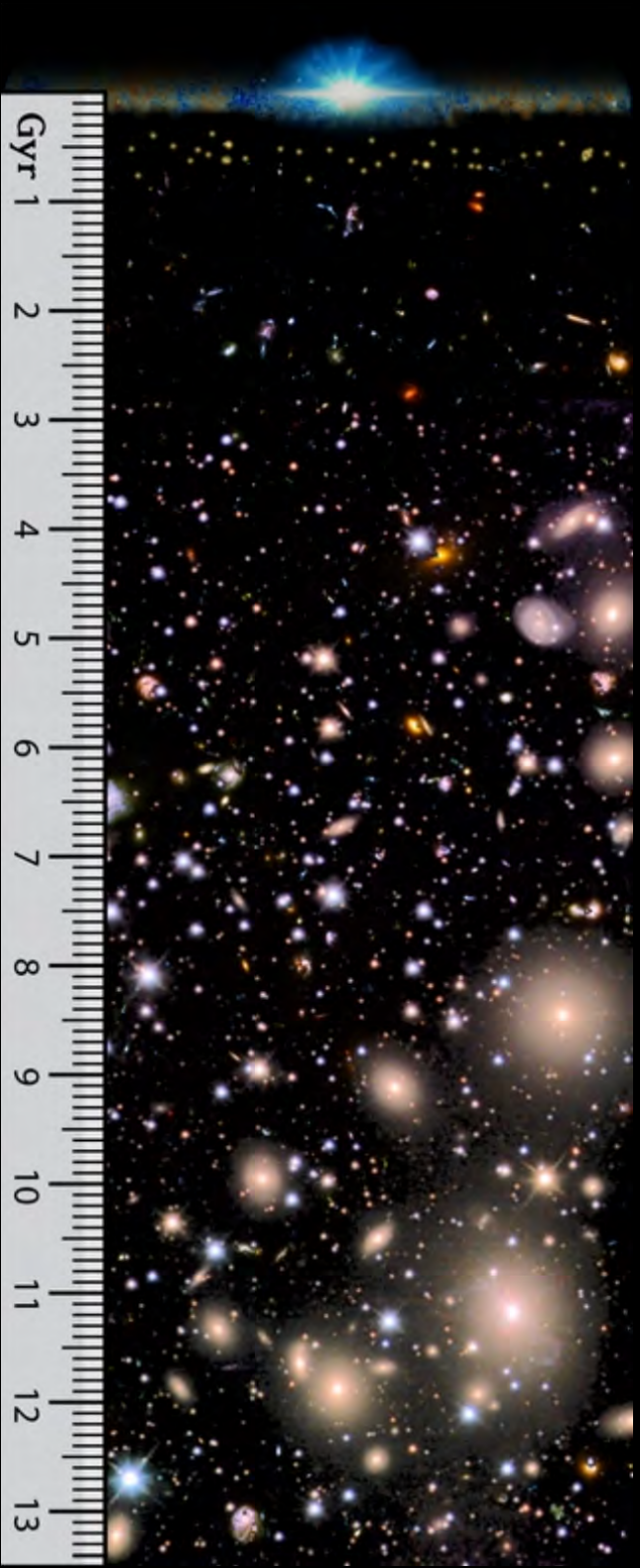


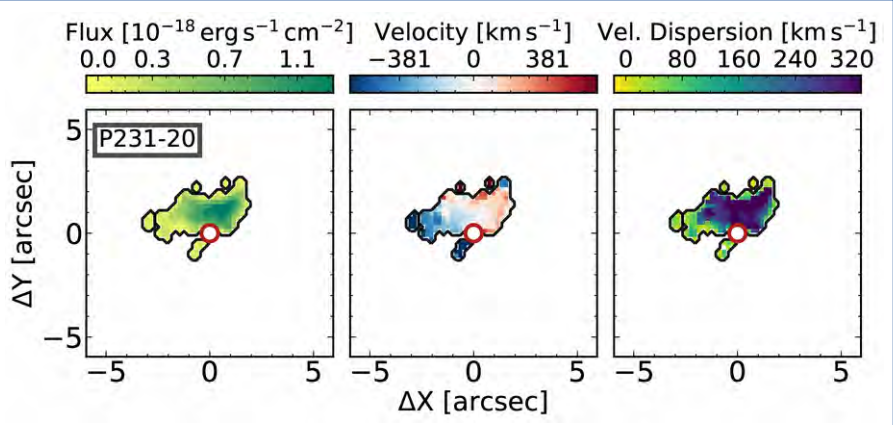
Farina et al. 2019, submitted



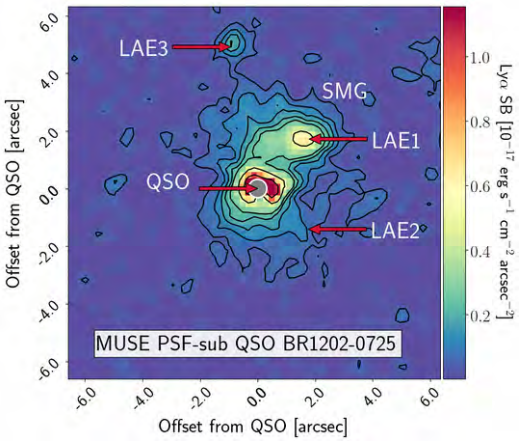


REQUIEM survey [>31QSOs at z~6]
Farina et al. 2019, sub.

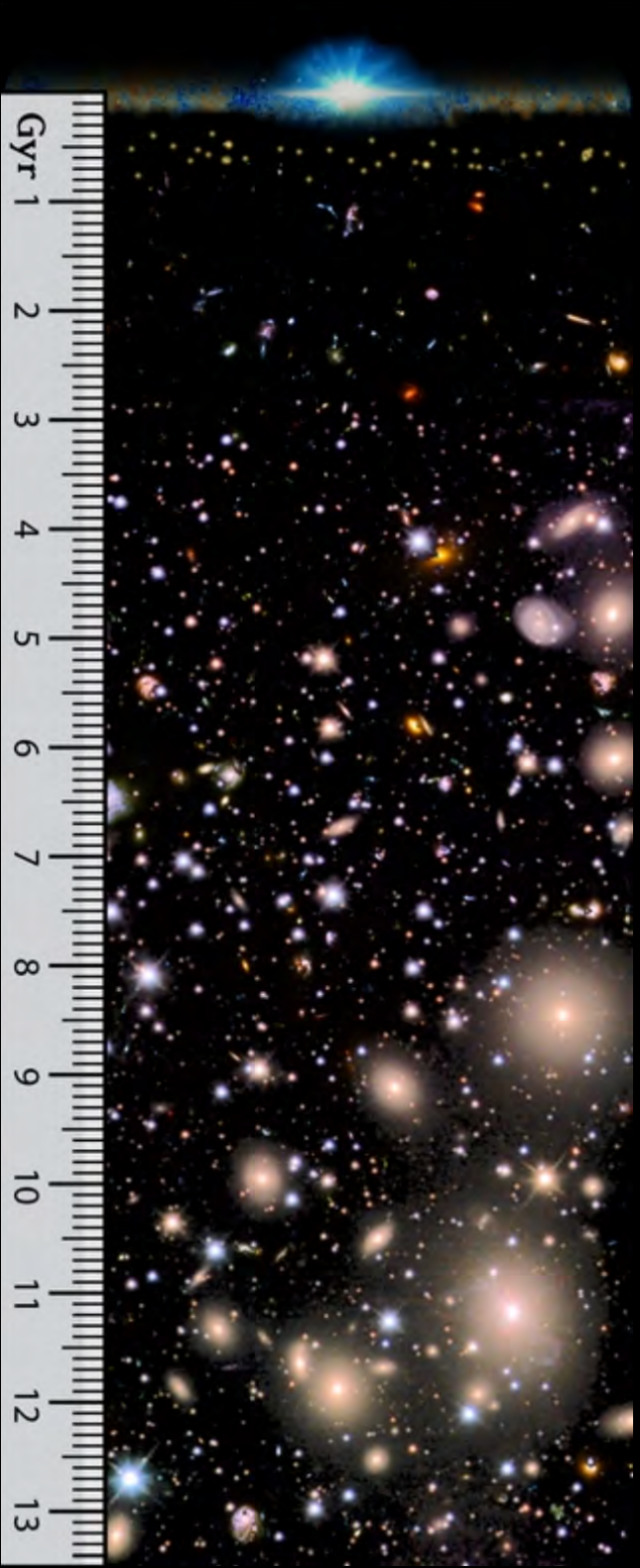


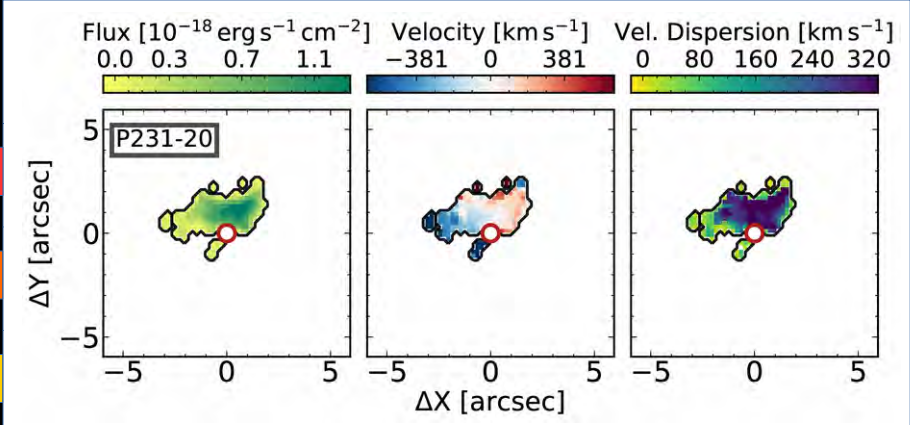


REQUIEM survey [>31QSOs at z~6]
Farina et al. 2019, sub.

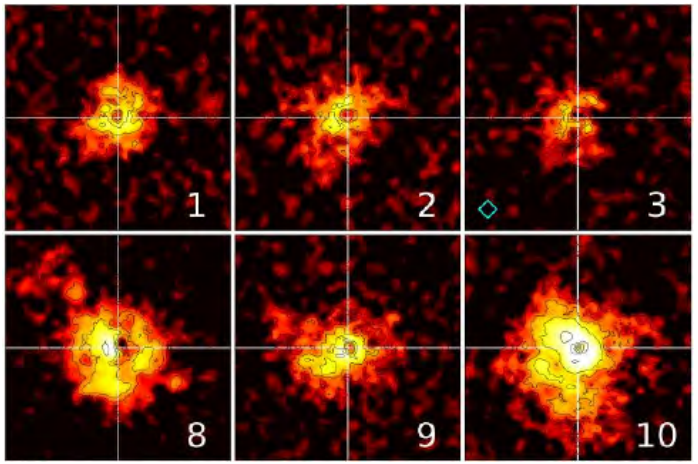


***post*–REQUIEM survey**
[>27 QSOs at z~4–5]
Farina+XX/Drake+XX

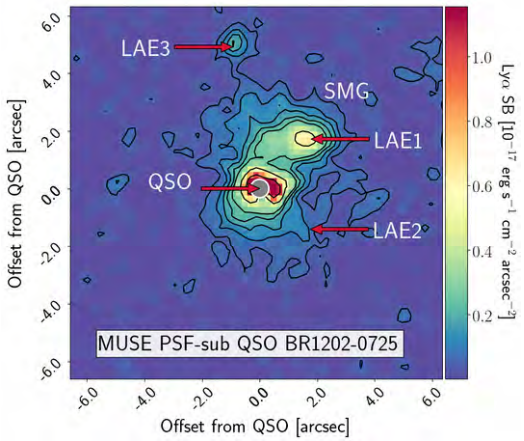




REQUIEM survey [>31QSOs at z~6]
Farina+19, sub.



QSO MUSEUM
[61 QSOs at z~3]
Arrigoni-Battaia+19
[+19 at z~3.5 Borisova+16]



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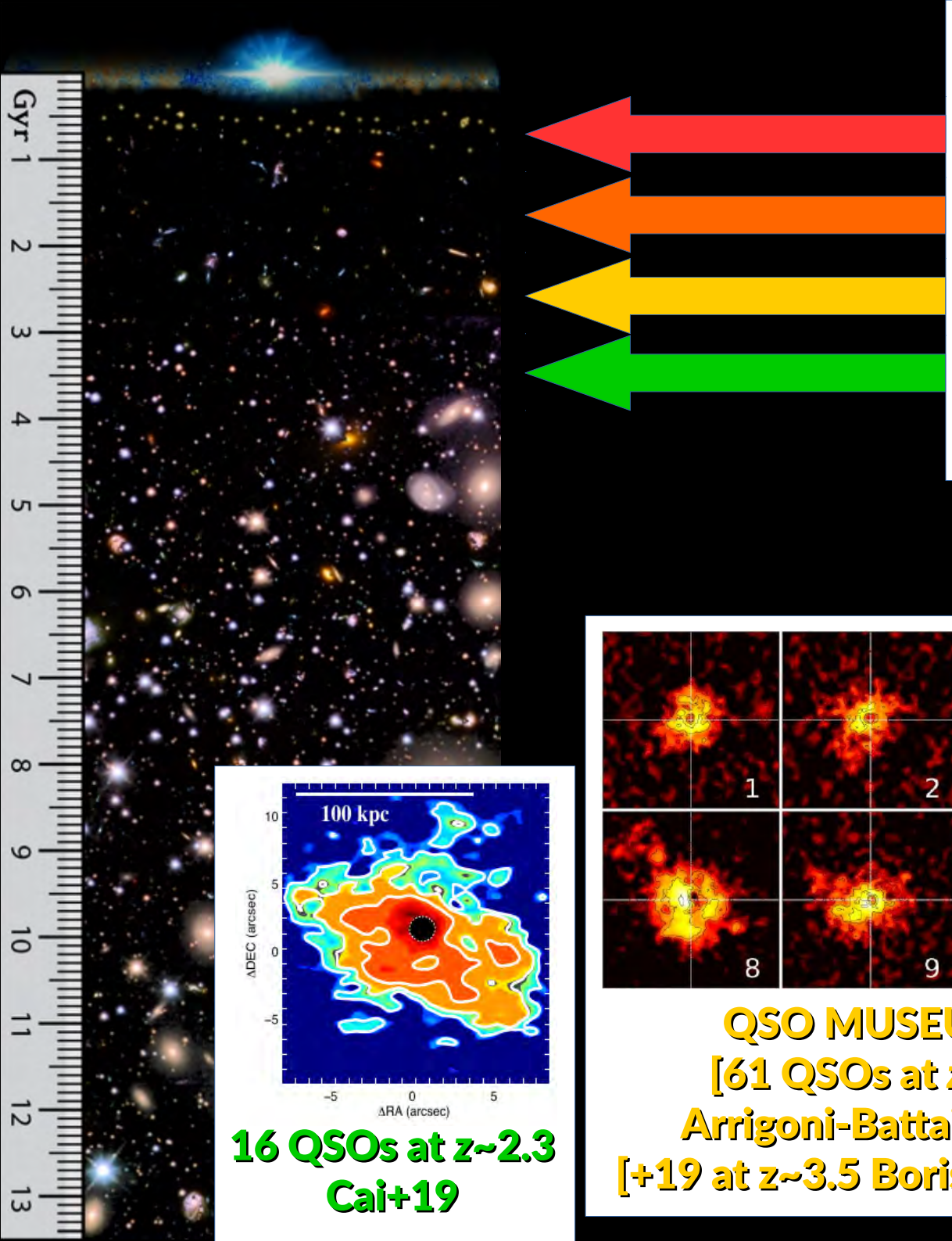
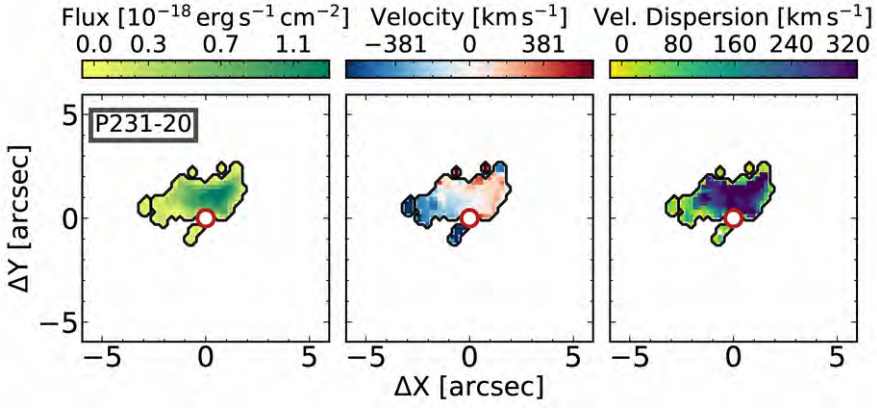
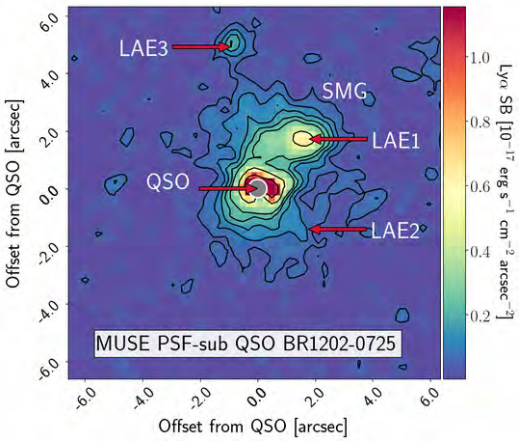
[>27 QSOs at z~4–5]
Farina+XX/Drake+XX

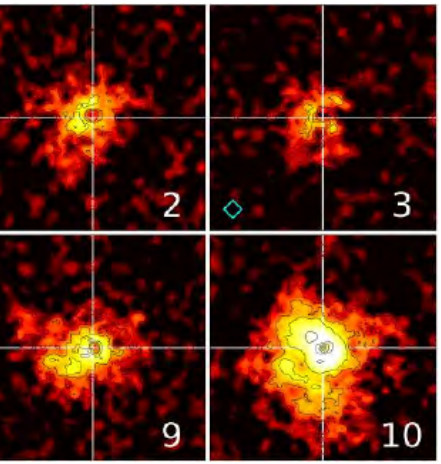




REQUIEM survey [>31QSOs at z~6]
Farina+19, sub.

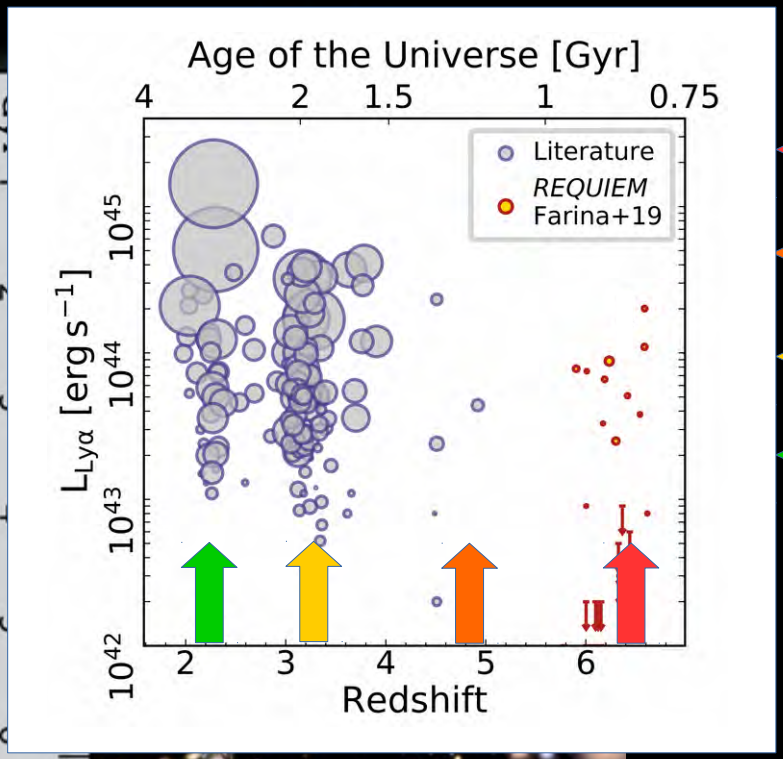


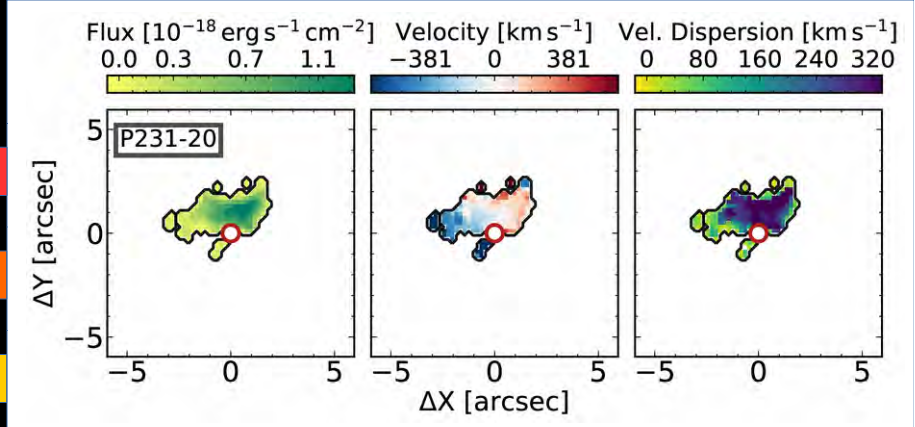
***post*–REQUIEM survey**
[>27 QSOs at z~4–5]
Farina+XX/Drake+XX



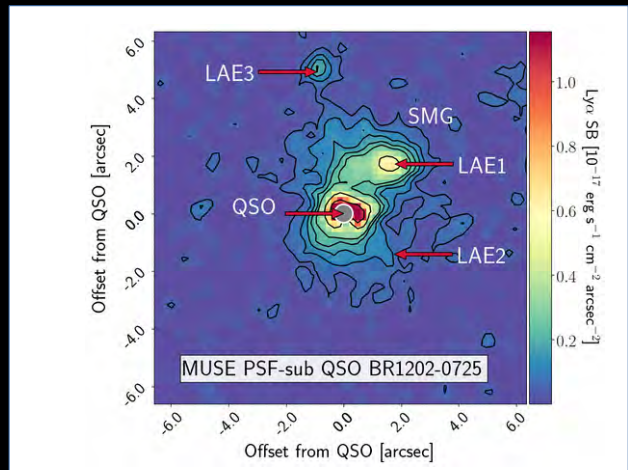
QSO MUSEUM
[61 QSOs at z~3]
Arrigoni-Battaia+19
[+19 at z~3.5 Borisova+16]

16 QSOs at z~2.3
Cai+19

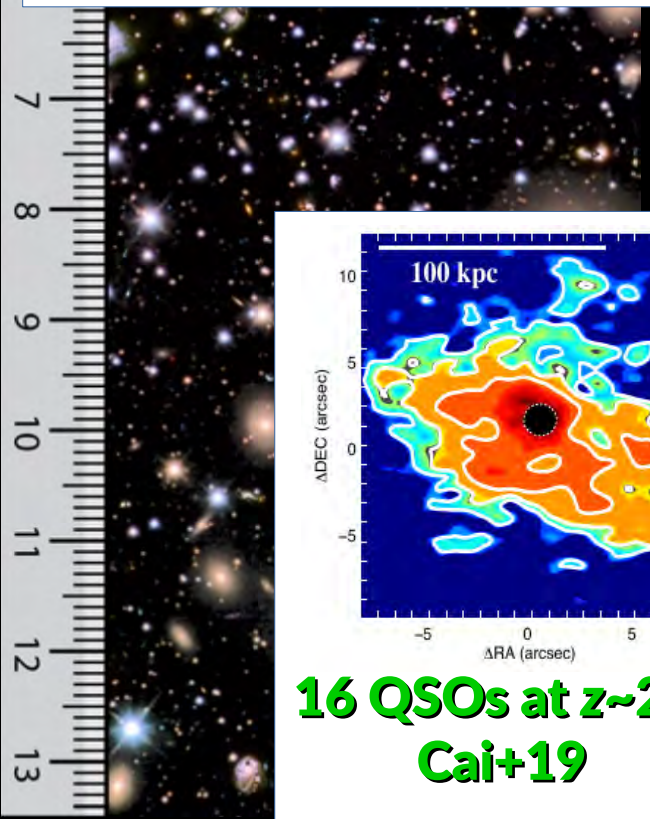




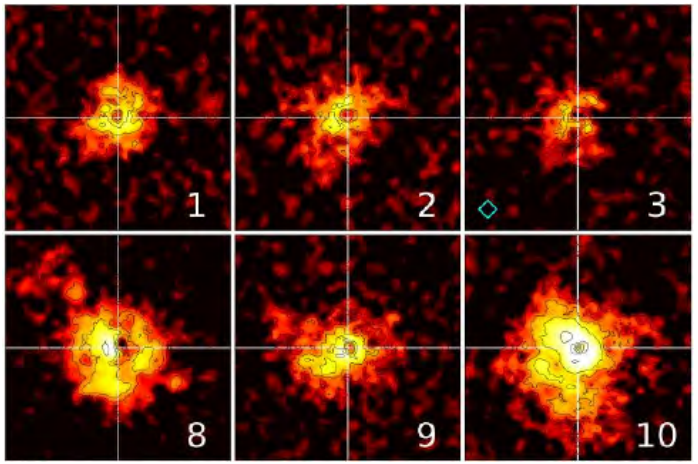
REQUIEM survey [>31QSOs at z~6]
Farina+19, sub.



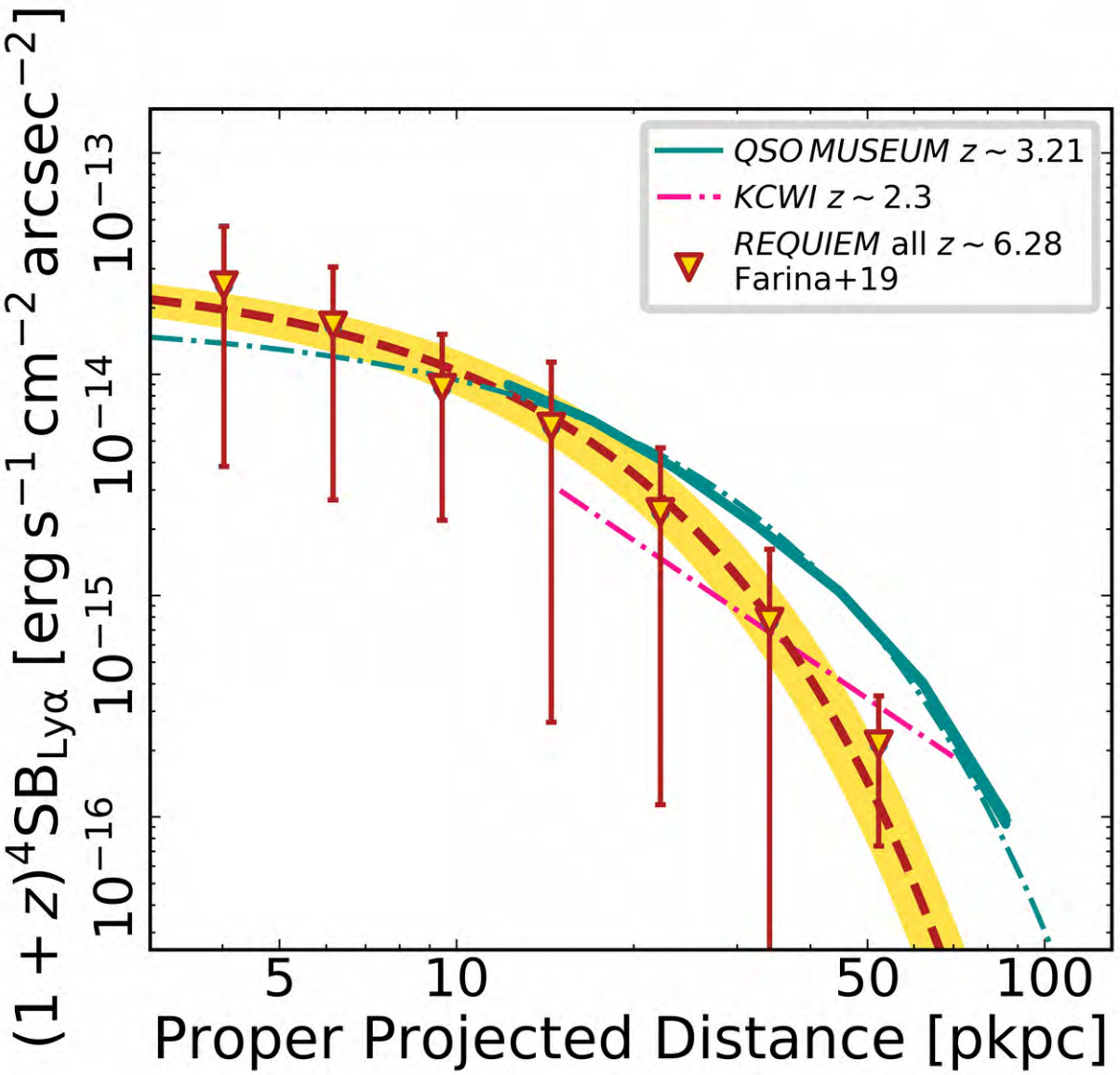
***post*–REQUIEM survey**
[>27 QSOs at z~4–5]
Farina+XX/Drake+XX



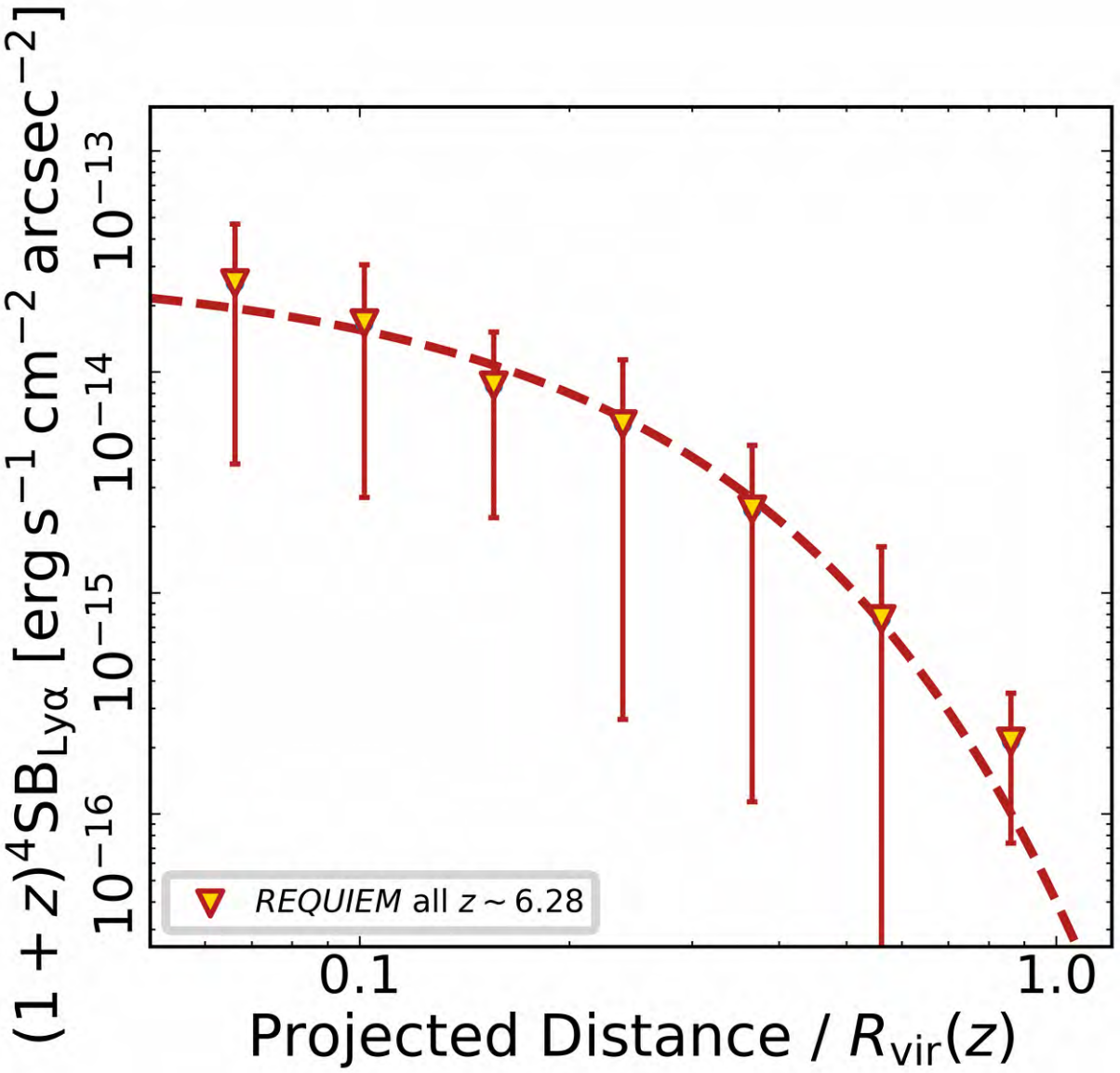
16 QSOs at z~2.3
Cai+19



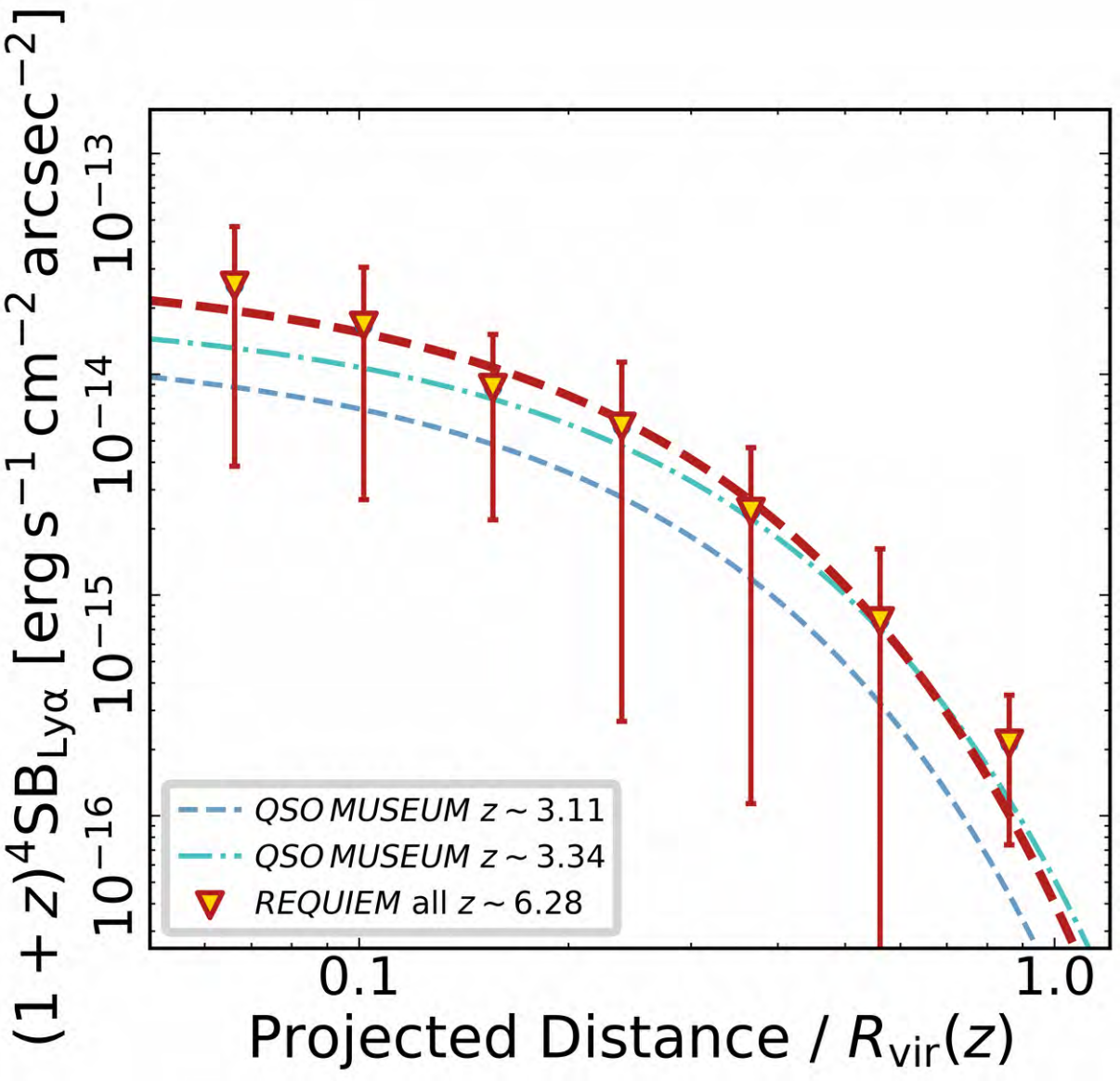
QSO MUSEUM
[61 QSOs at z~3]
Arrigoni-Battaia+19
[+19 at z~3.5 Borisova+16]


QSO MUSEUM $z \sim 3.21$
KCWI $z \sim 2.3$
REQUIEM all $z \sim 6.28$
Farina+19
$(1+z)^4 SB_{Ly\alpha}$ [erg s^{-1} cm^{-2} arcsec^{-2}]
10^{-13}
10^{-14}
10^{-15}
10^{-16}
5
10
50
100
Proper Projected Distance [pkpc]

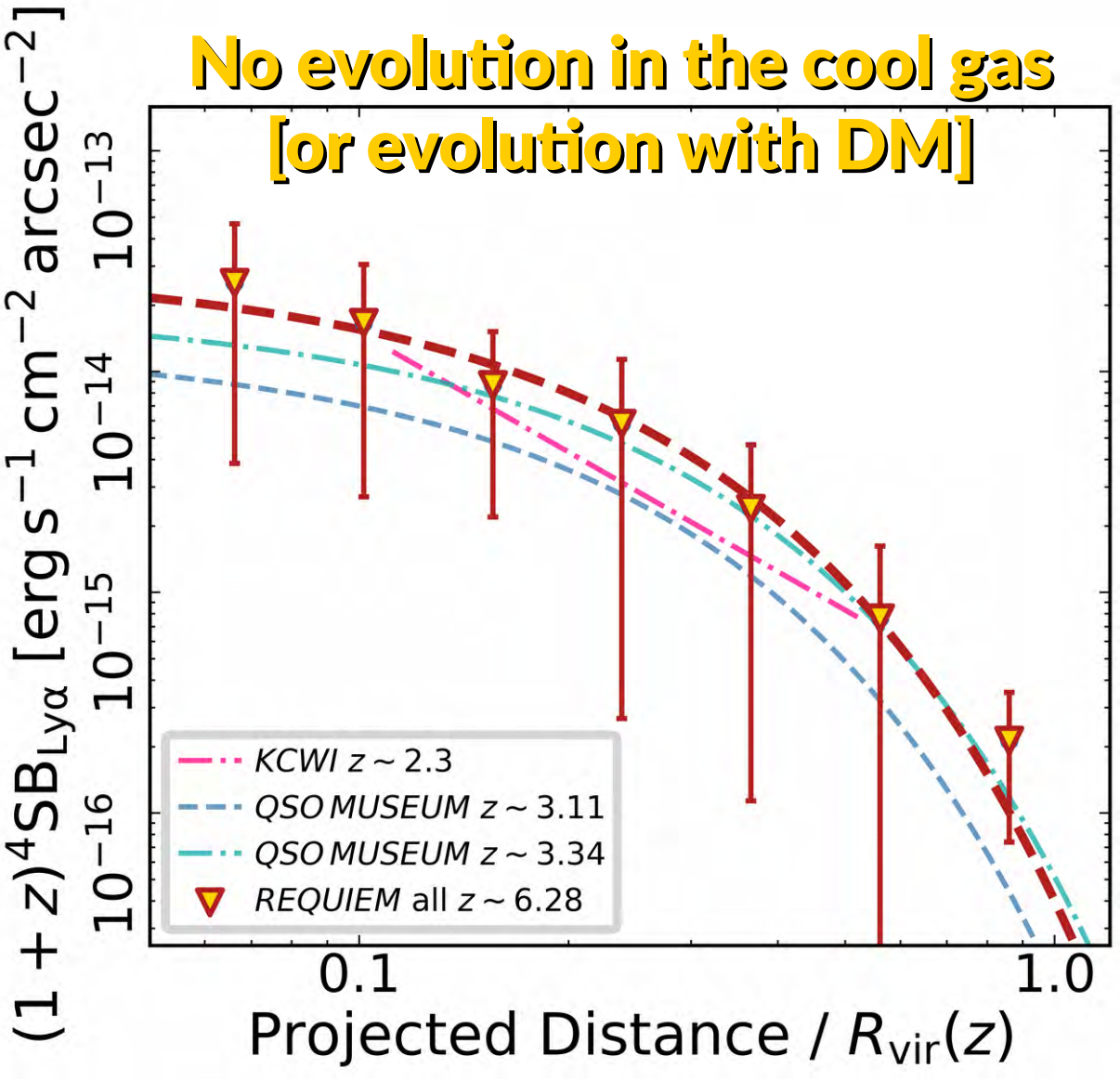
The History of the CGM



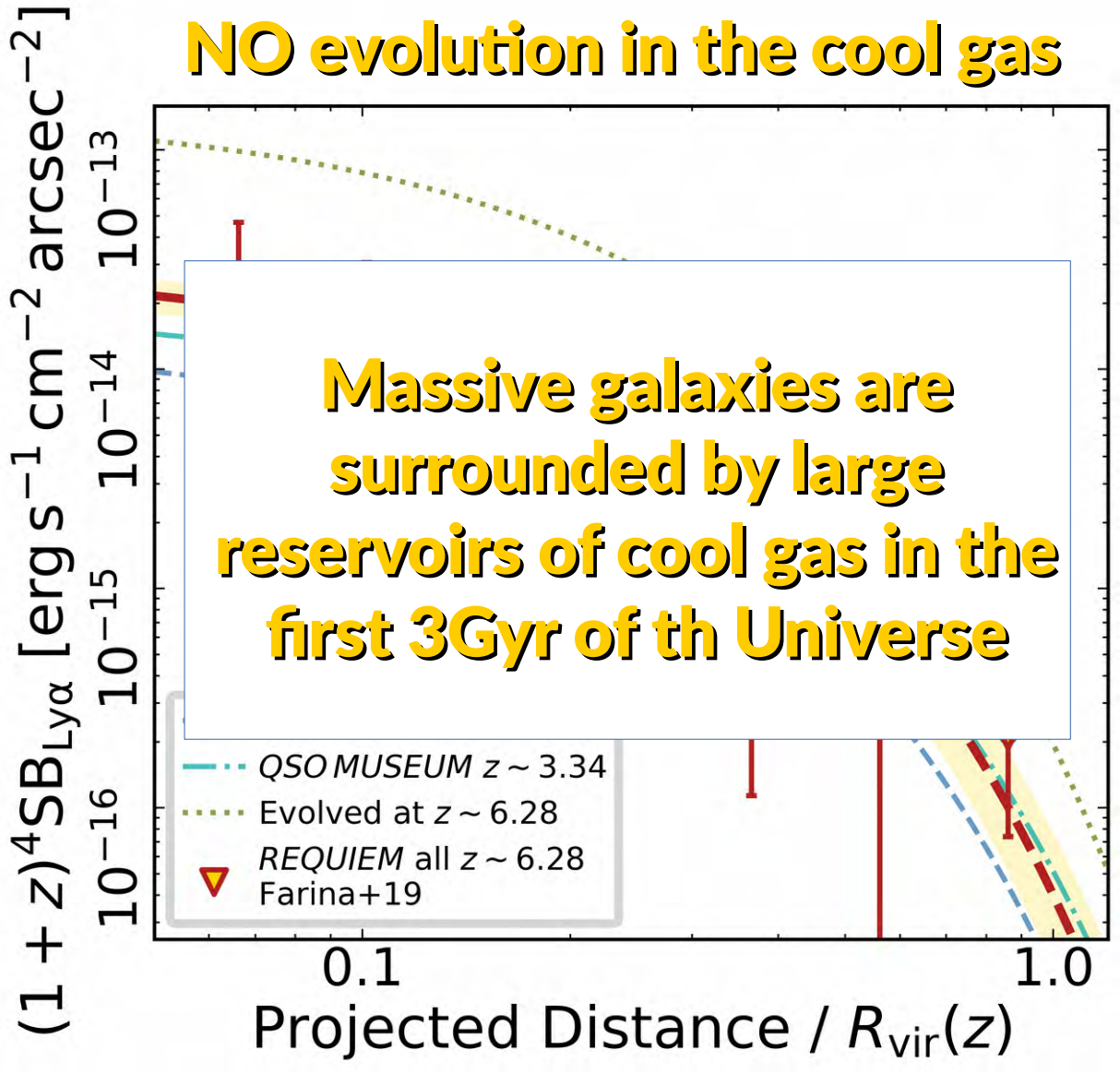
The History of the CGM



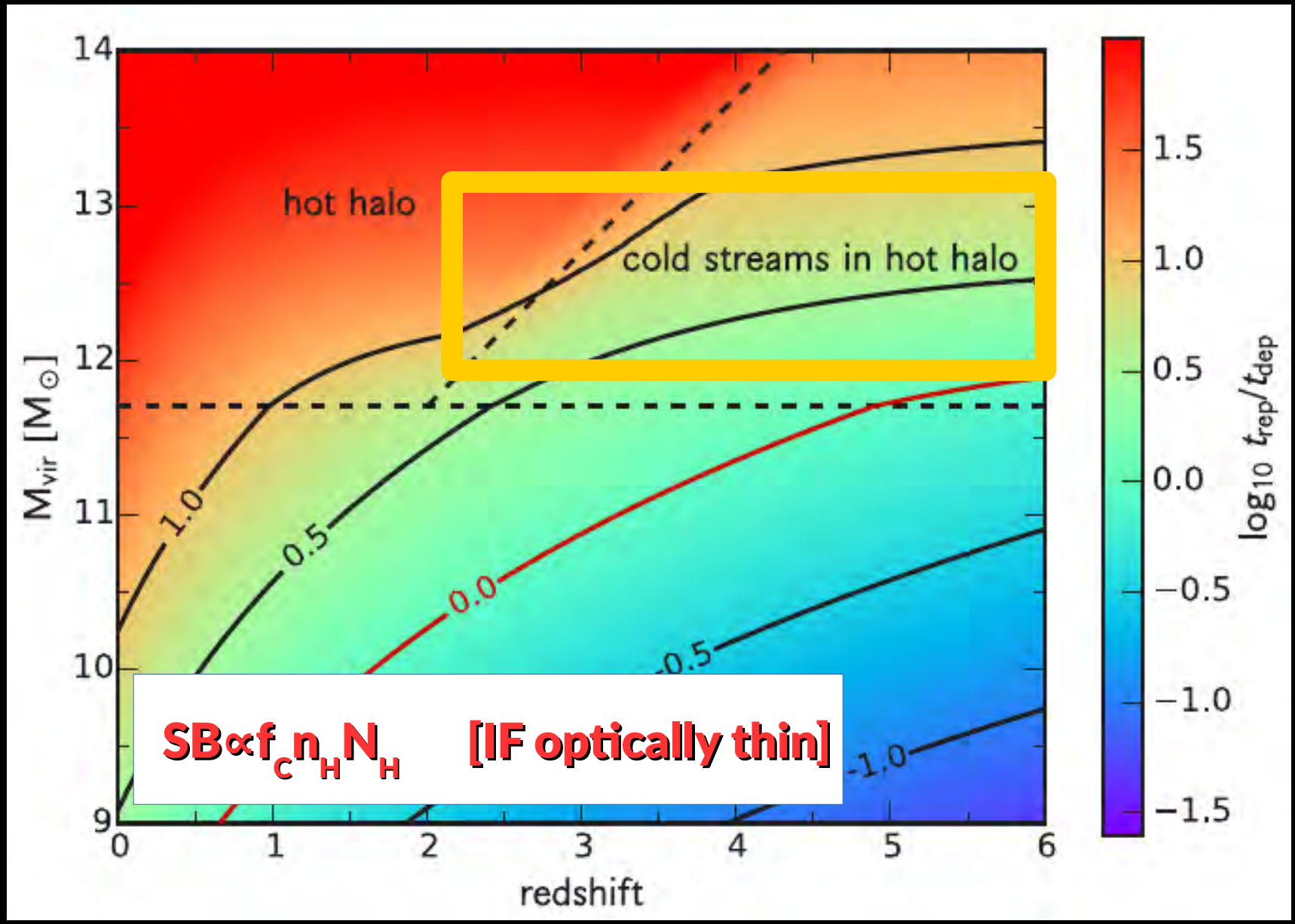
The History of the CGM



The History of the CGM



Is this Teaching us Something?

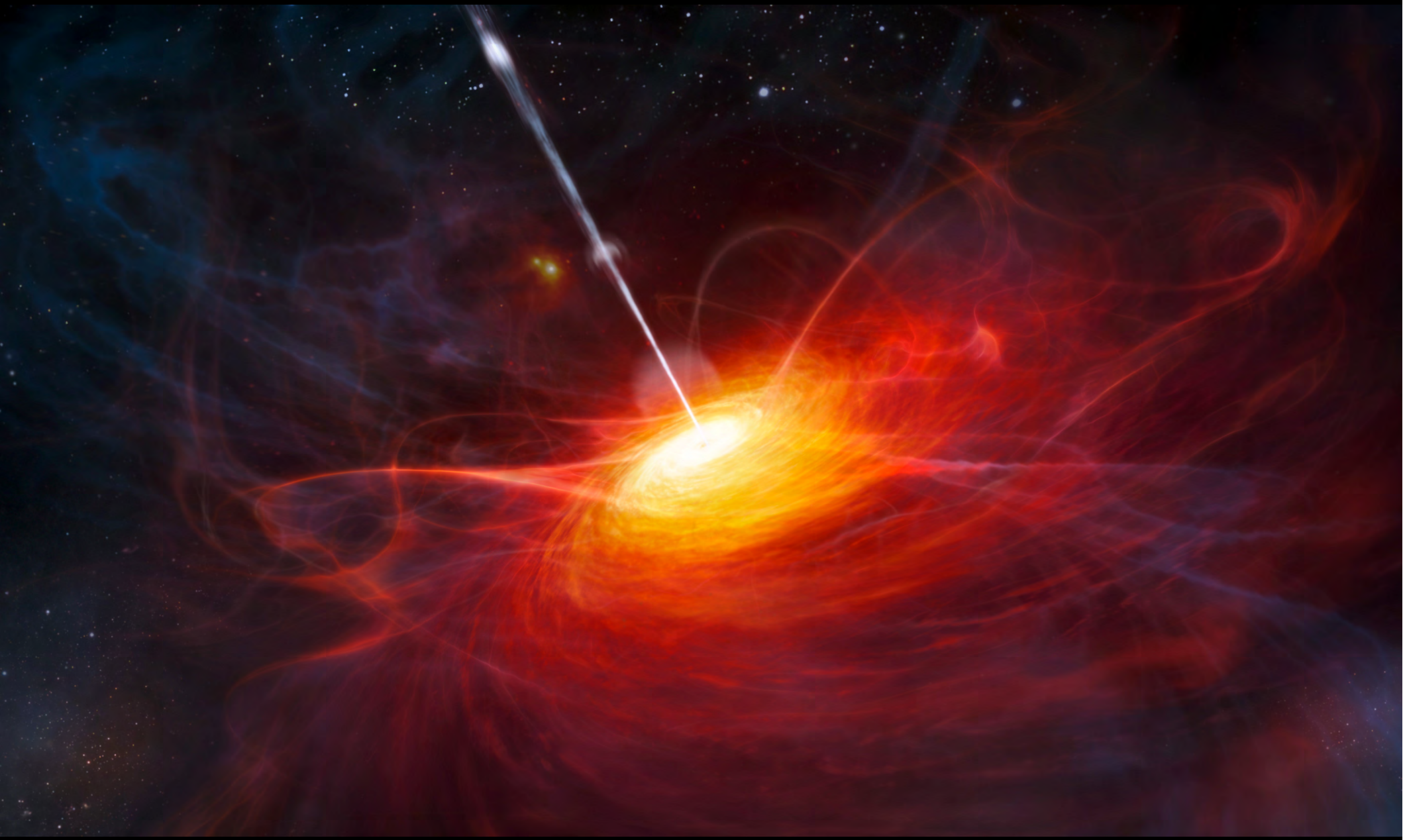


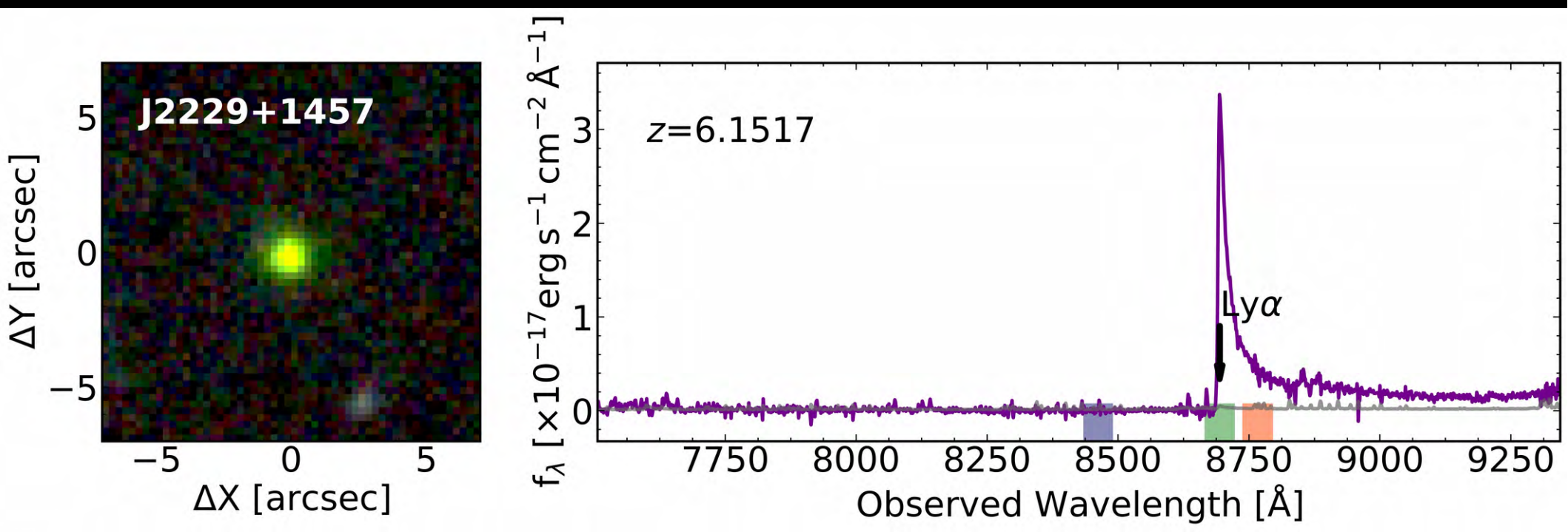
Dekel et al. 2019

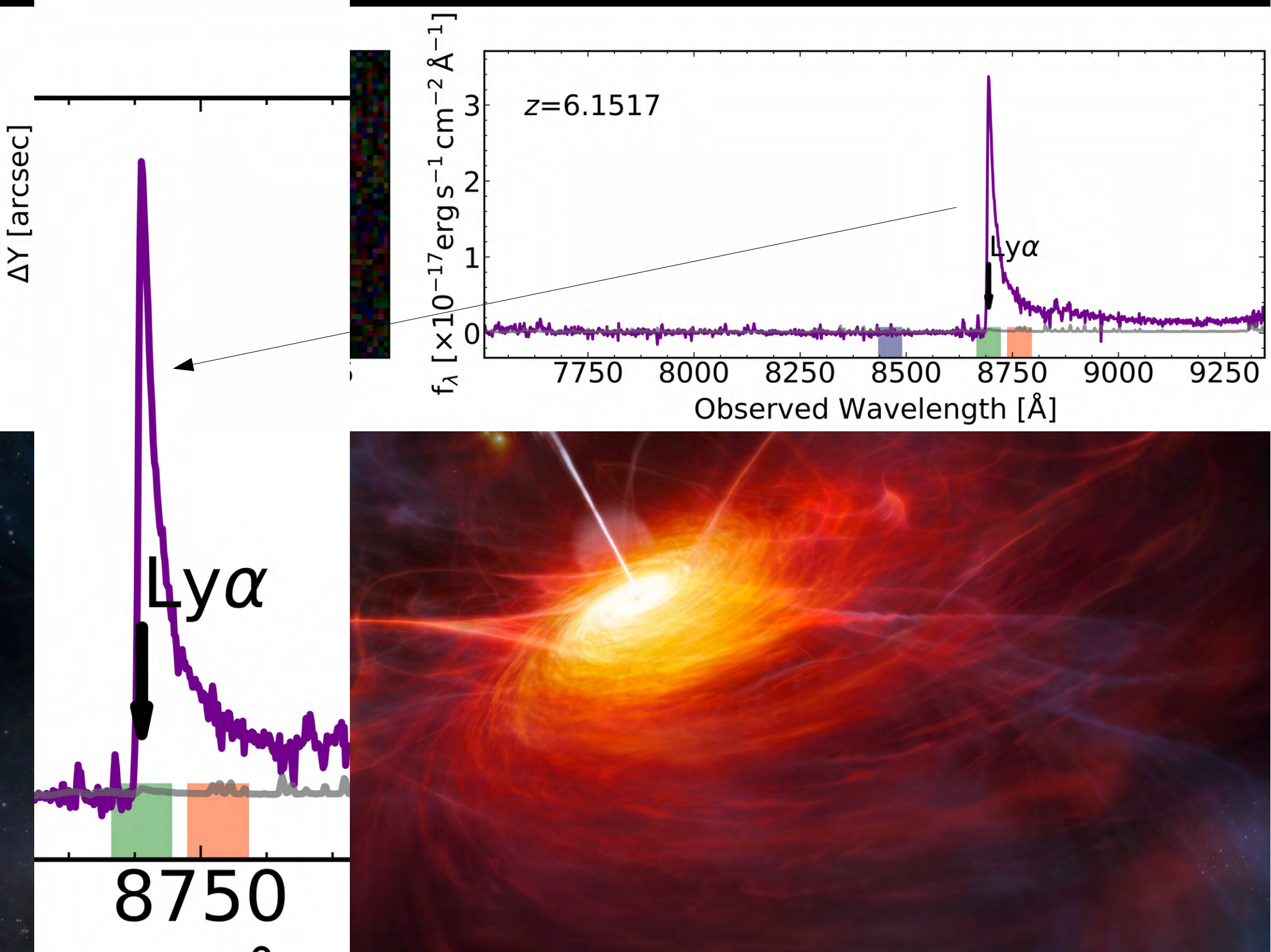
We can detect the CGM of massive galaxies up to z~6.6

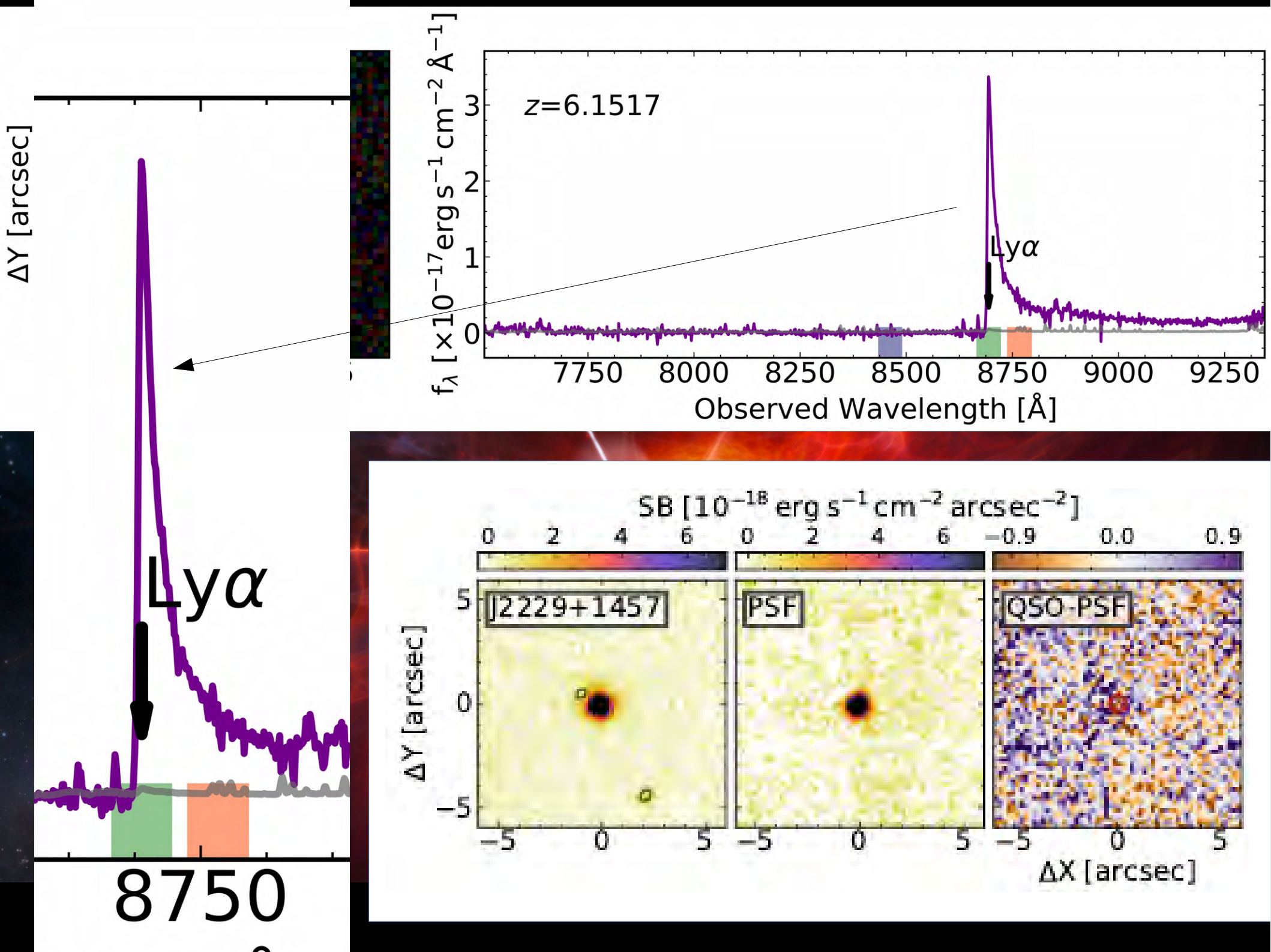
(No)evolution from z~6 to z~2
[~3Gyr of Cosmic History]

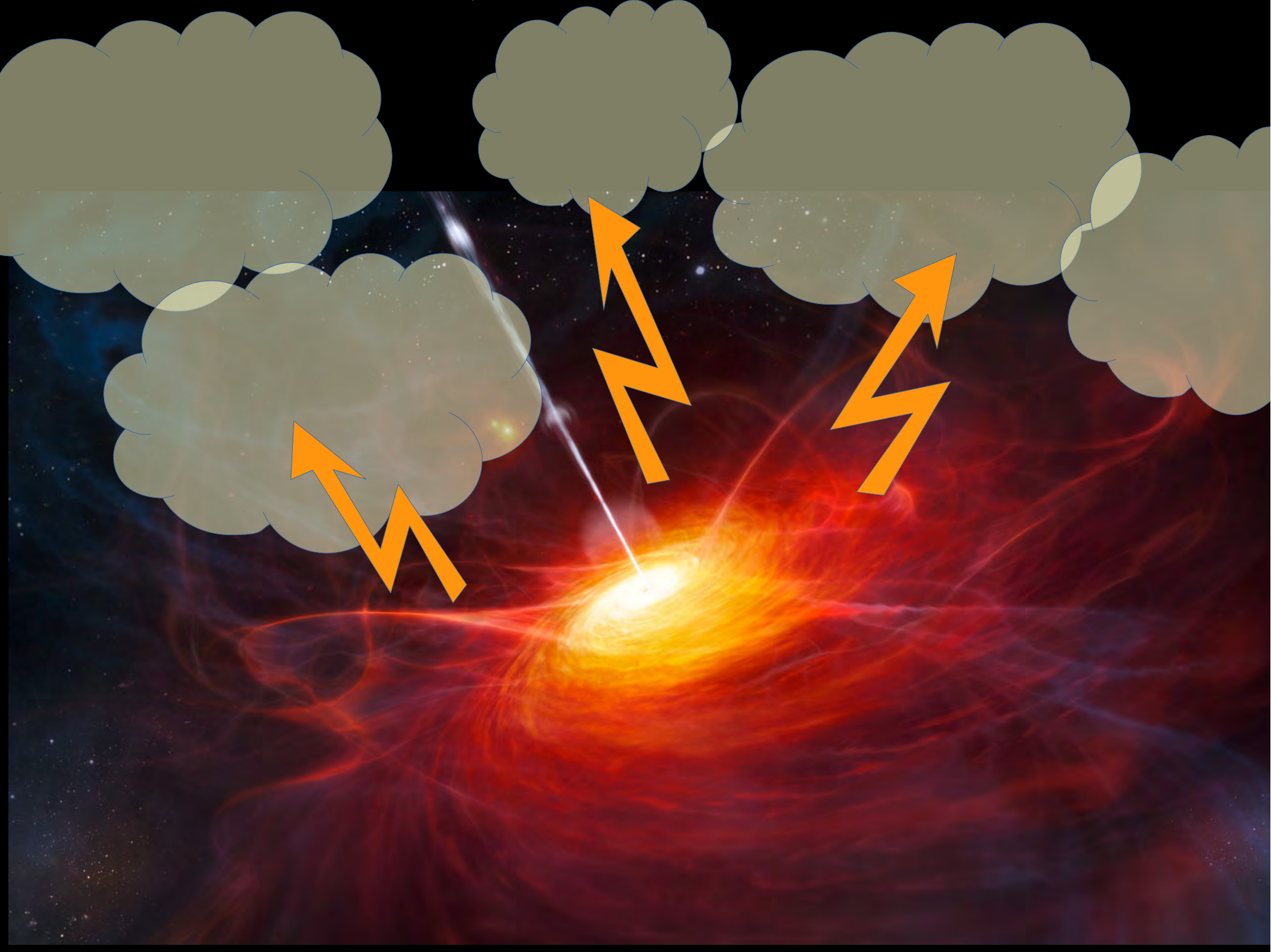
https://emastro.github.io/requiem/index.html

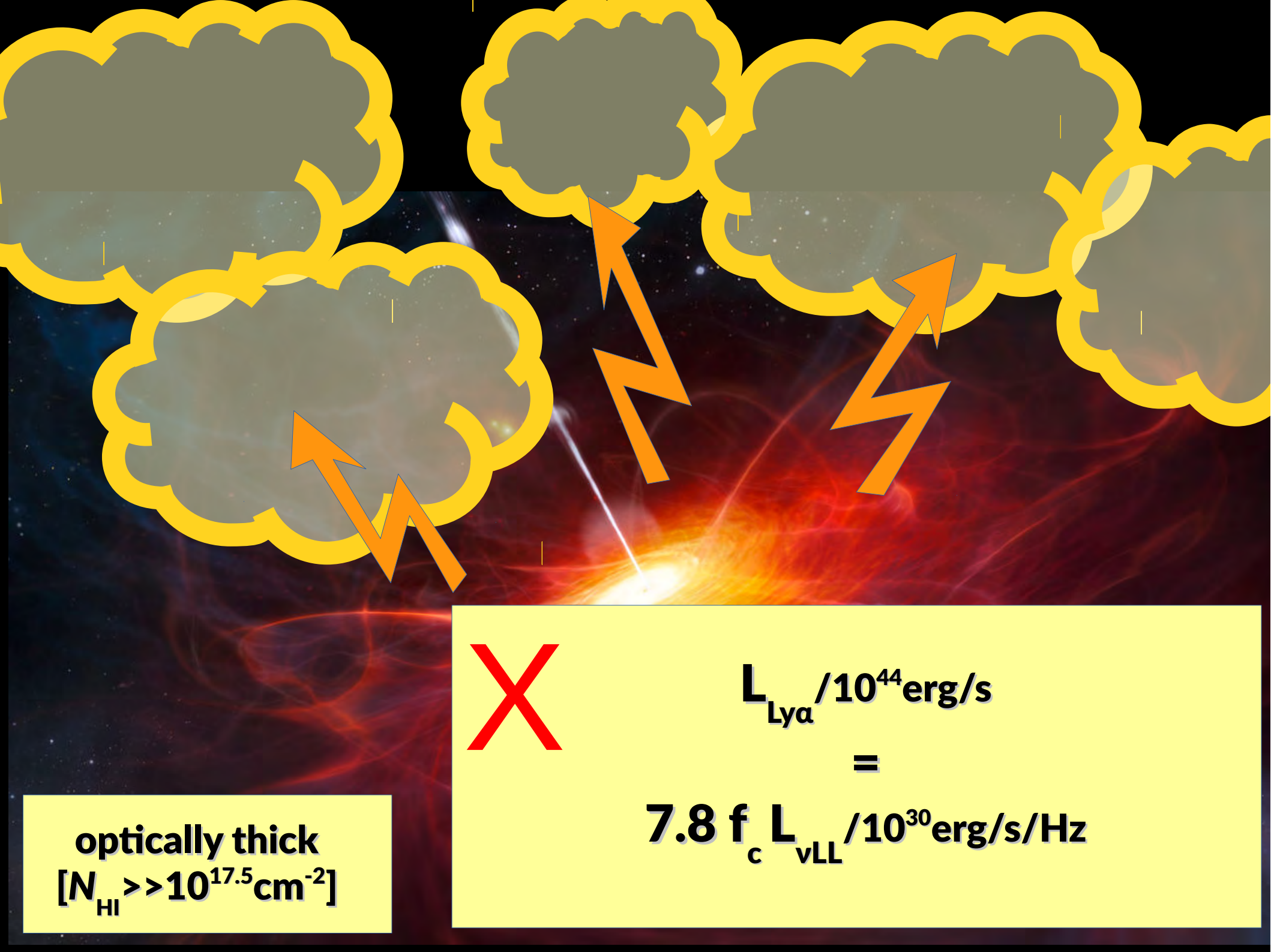


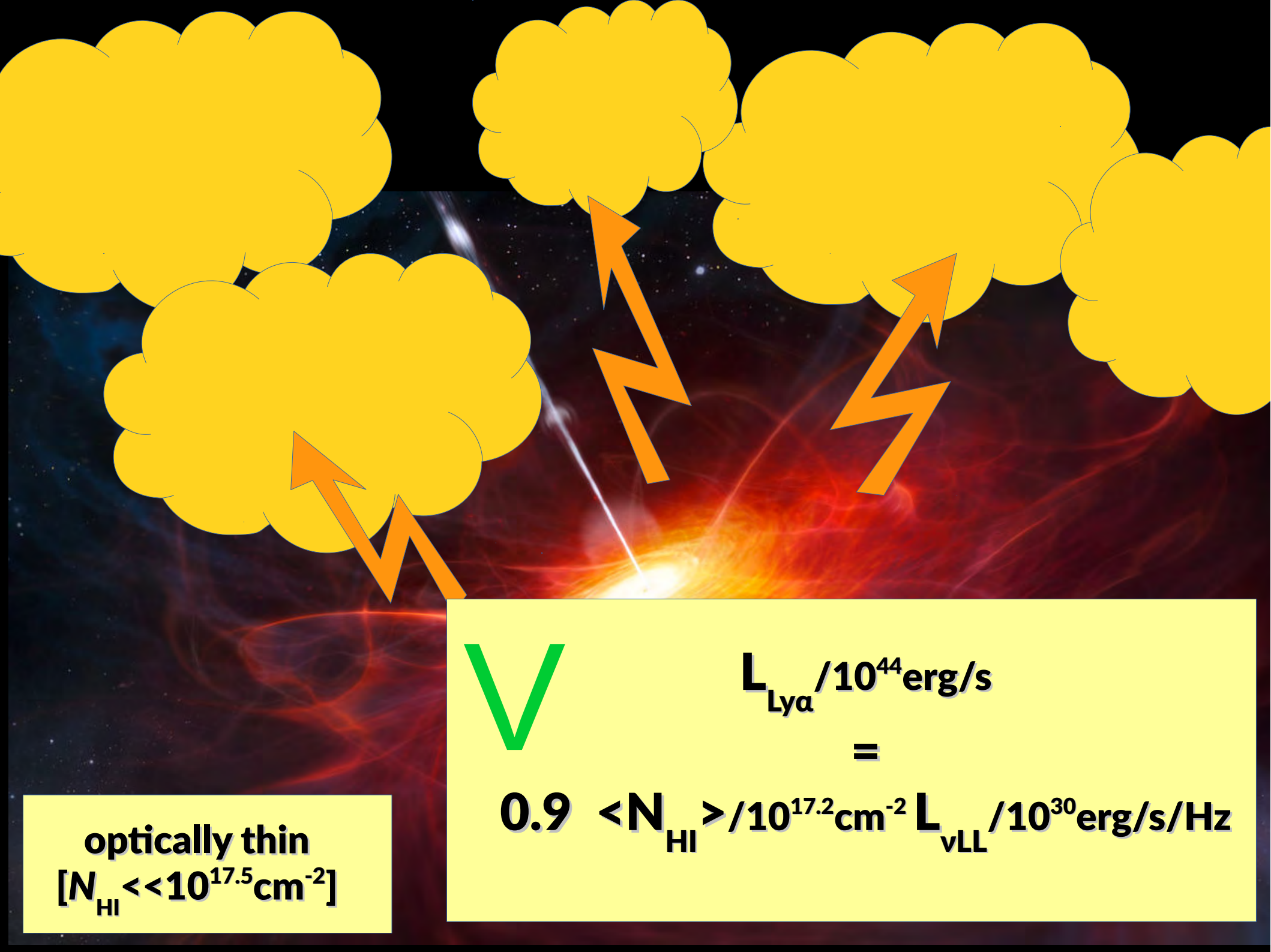

J2229+1457
ΔY [arcsec]
ΔX [arcsec]
z=6.1517
Lyα
f_λ [×10^−17 erg s^−1 cm^−2 Å^−1]
Observed Wavelength [Å]

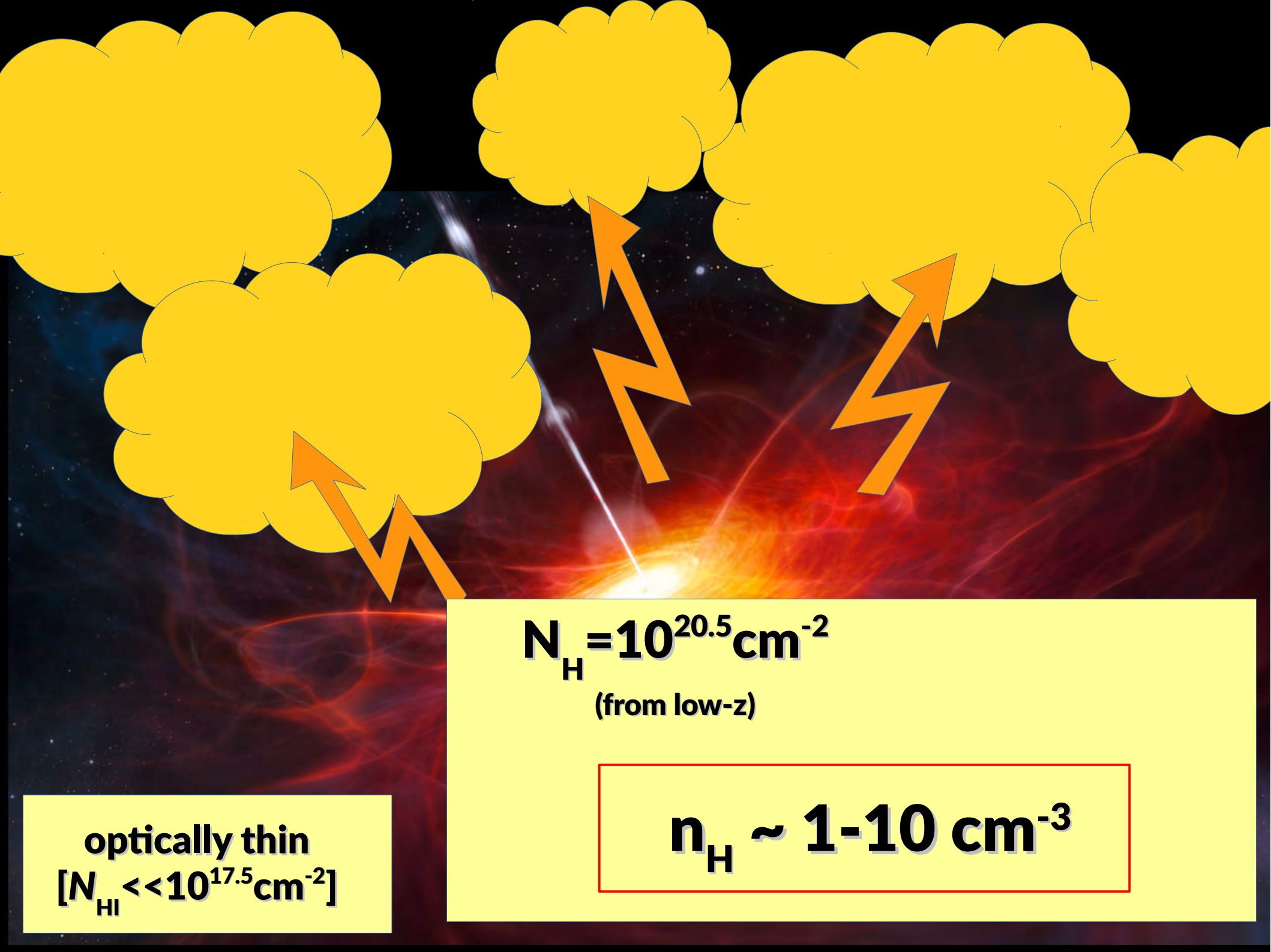

ΔY [arcsec]
z=6.1517
Lyα
f_λ [$\times 10^{-17}$ erg s^{-1} cm^{-2} Å^{-1}]
Observed Wavelength [Å]
7750
8000
8250
8500
8750
9000
9250
0
1
2
3
Lyα
8750


ΔY [arcsec]
Lyα
8750
z=6.1517
Lyα
f_λ [×10^−17 erg s^−1 cm^−2 Å^−1]
Observed Wavelength [Å]
7750
8000
8250
8500
8750
9000
9250
SB [10^−18 erg s^−1 cm^−2 arcsec^−2]
J2229+1457
PSF
QSO-PSF
ΔY [arcsec]
ΔX [arcsec]

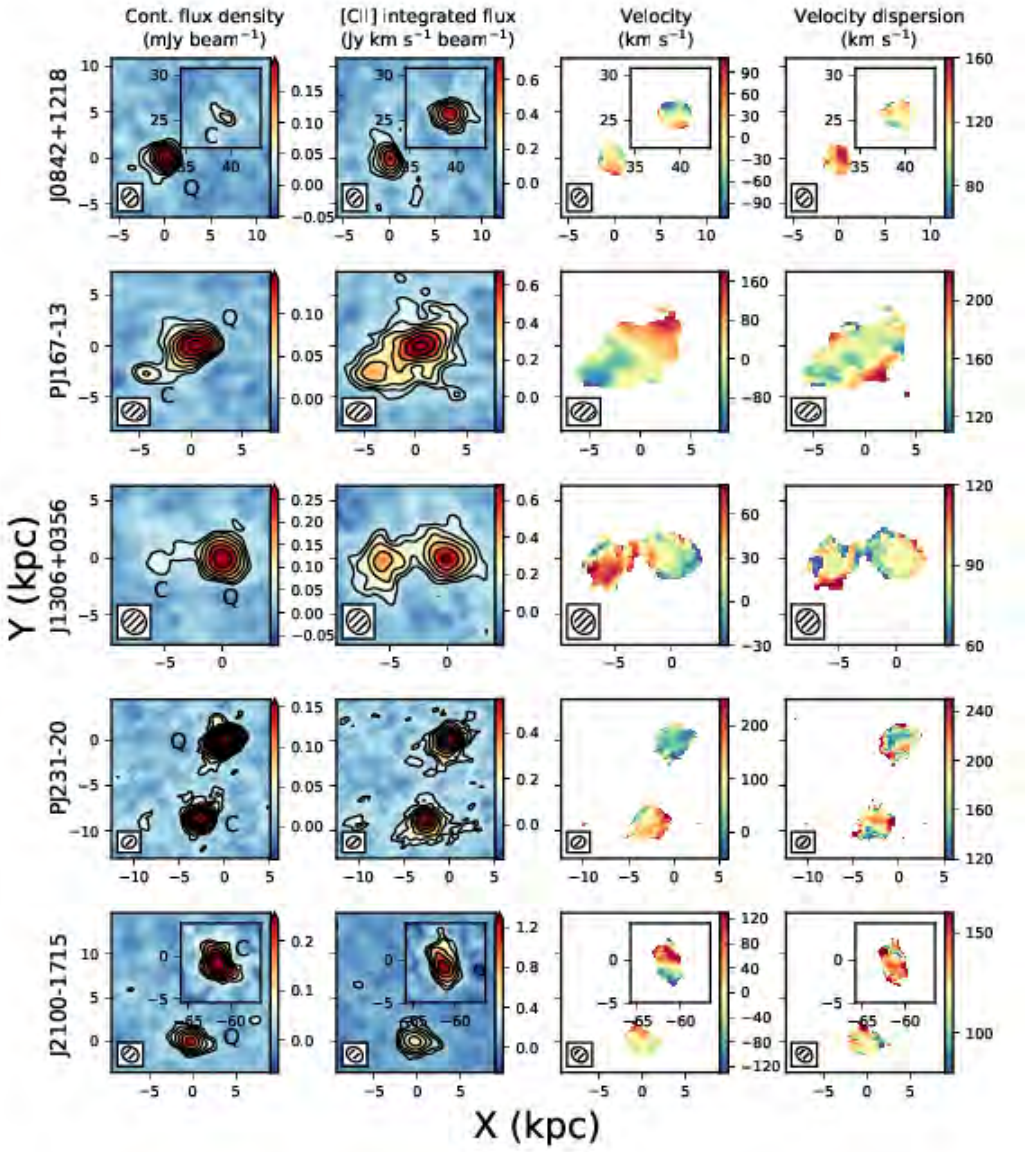



optically thick
[N_{HI}>>$10^{17.5}$cm^{-2}]
X
$L_{Ly\alpha}/10^{44}$erg/s
=
$7.8\, f_c\, L_{vLL}/10^{30}$erg/s/Hz


optically thin
[N_{HI}<<$10^{17.5}$cm^{-2}]
V
$L_{Ly\alpha}/10^{44}$erg/s
=
0.9 <N_{HI}>/$10^{17.2}$cm^{-2} $L_{vLL}/10^{30}$erg/s/Hz


$N_H = 10^{20.5} cm^{-2}$
(from low-z)
$n_H \sim 1\text{-}10\ cm^{-3}$
optically thin
[$N_{HI} << 10^{17.5} cm^{-2}$]

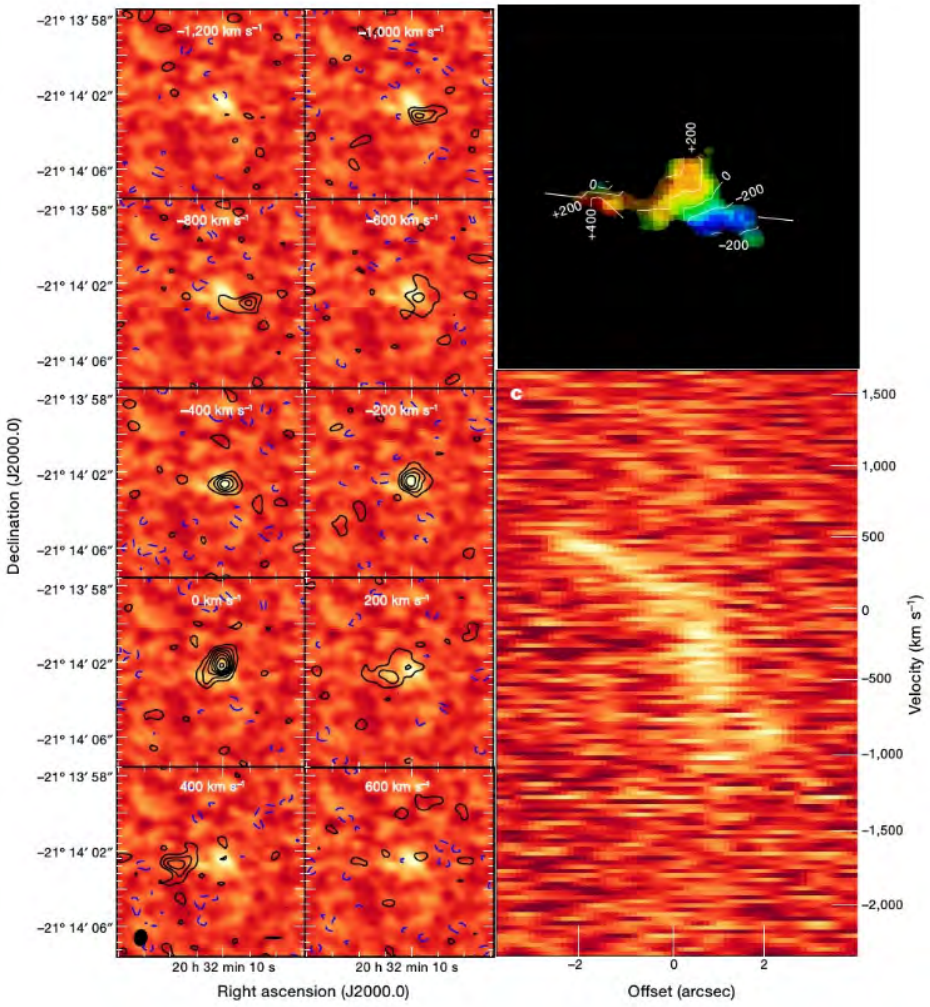
an ALMA view of the first QSOs



25 kpc

ΔV>1000km/s

$L_{[CII]}$~1.9x10^{9}L$_\odot$



Neeleman, .., Farina, .. , et al. 2019