Shaping Lyα profile in disky dwarf galaxies

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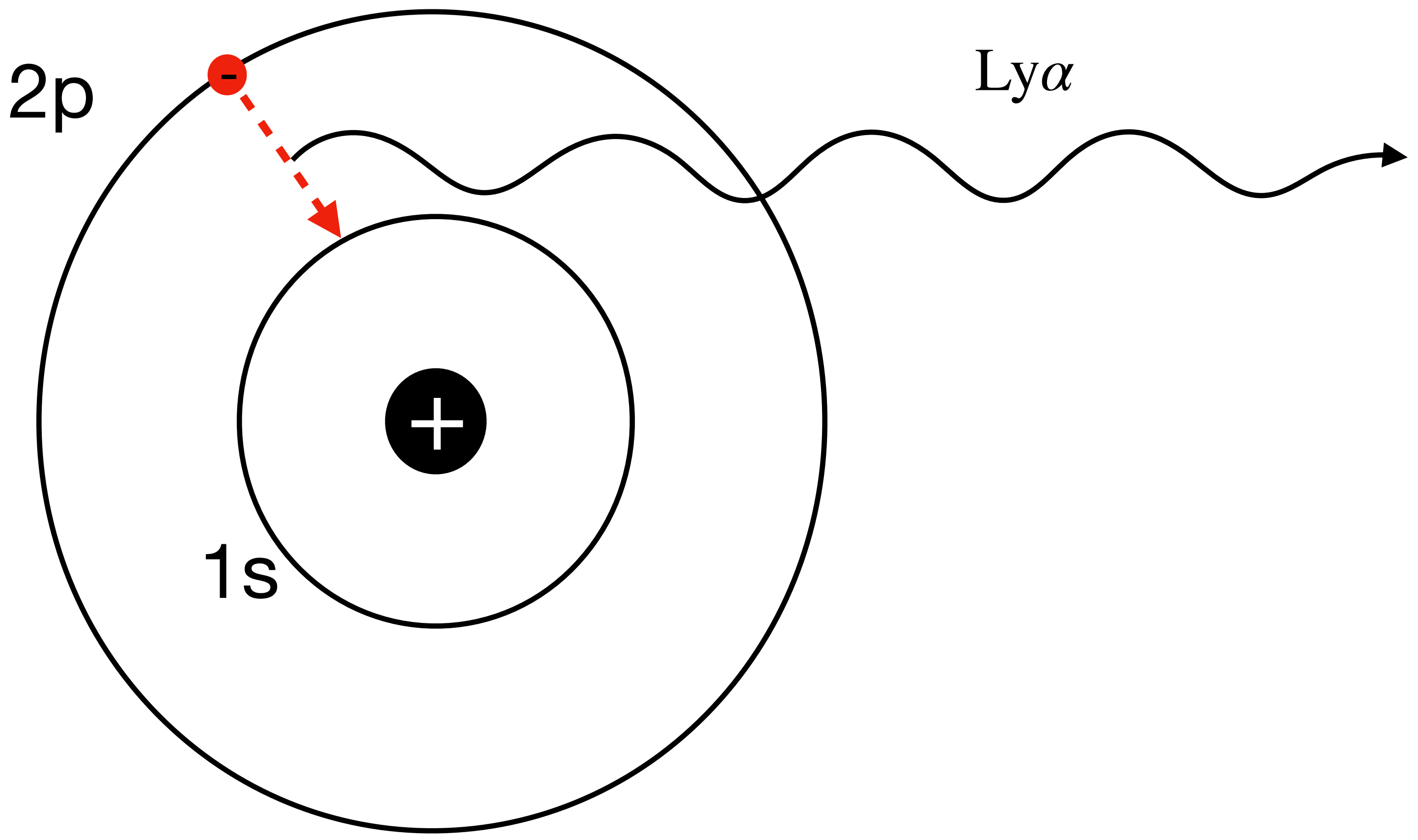
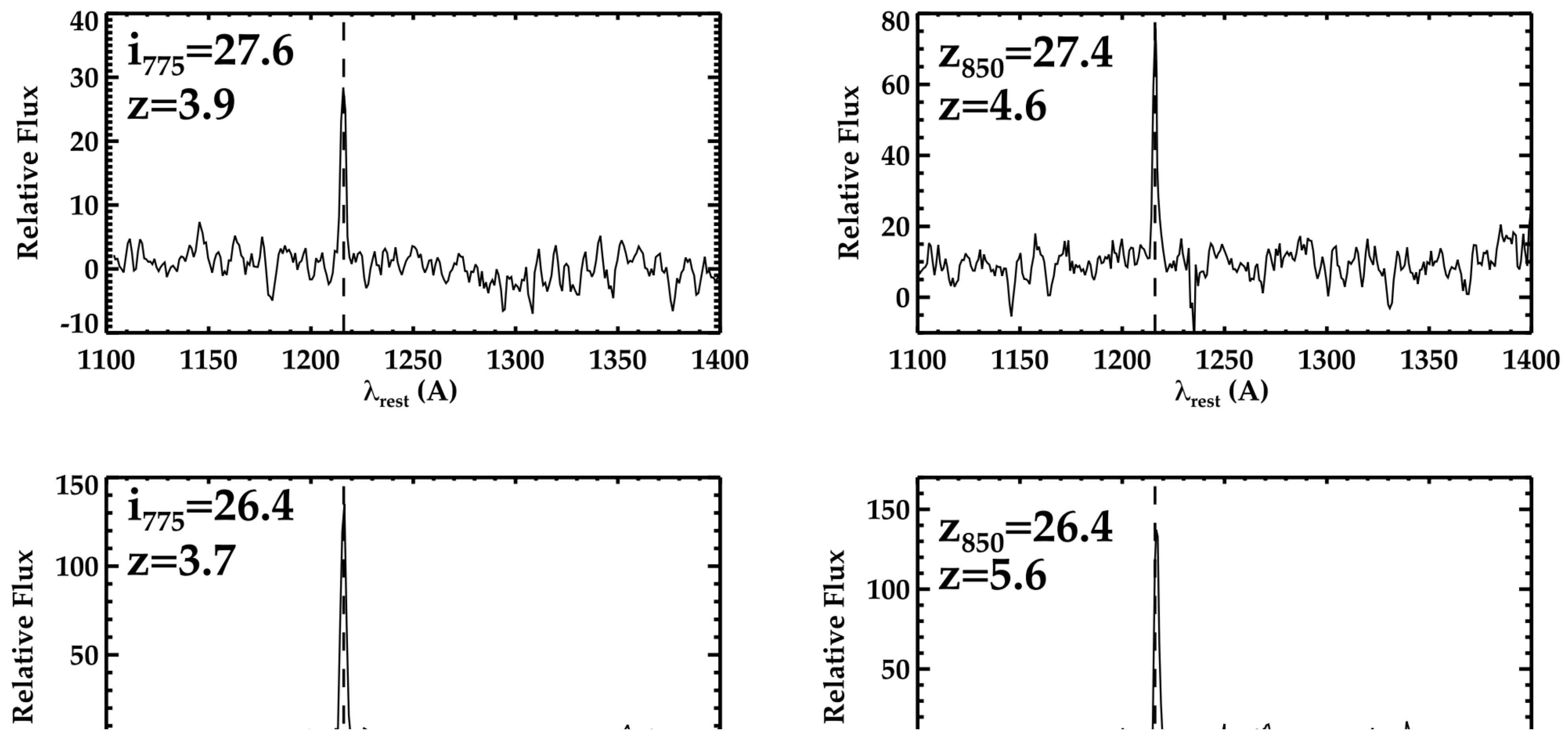
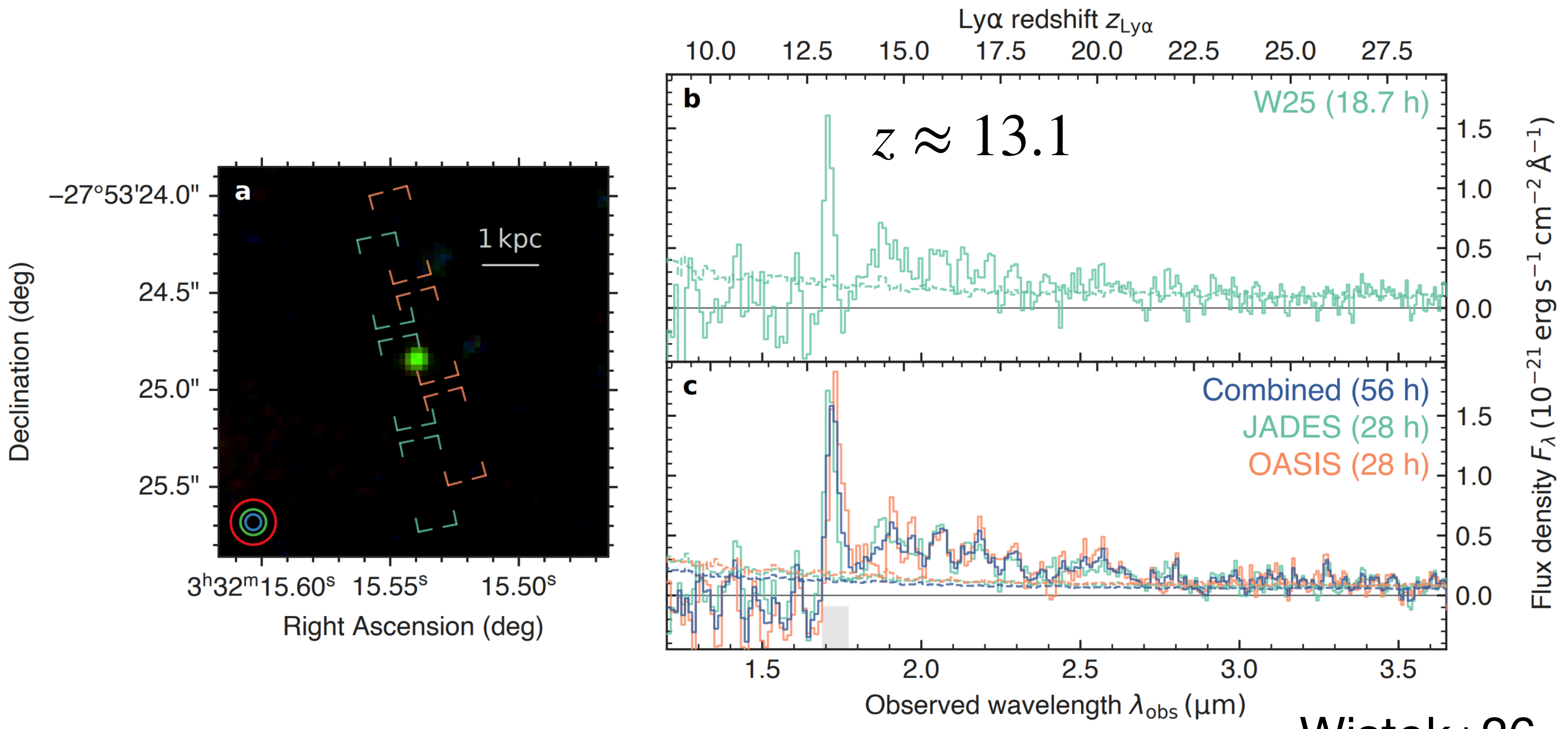
What is Lyα?

$\tau_\alpha = A_\alpha^{-1} \approx 10^{-9}\,\mathrm{s}$







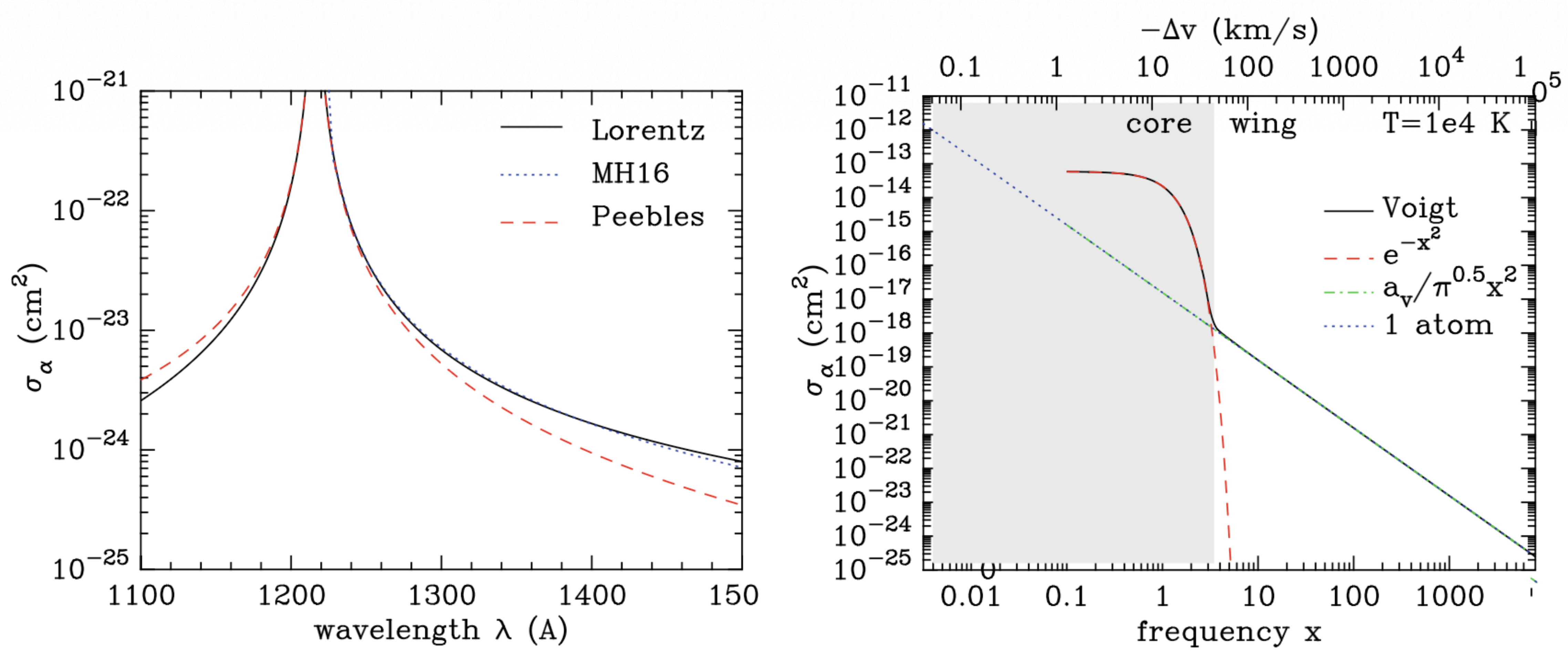
Wistok+26

Resonance line of hydrogen

- Large cross-section = High probability of emission
- $\mathrm{H\,I}$ abundance

→ Brightest emission line

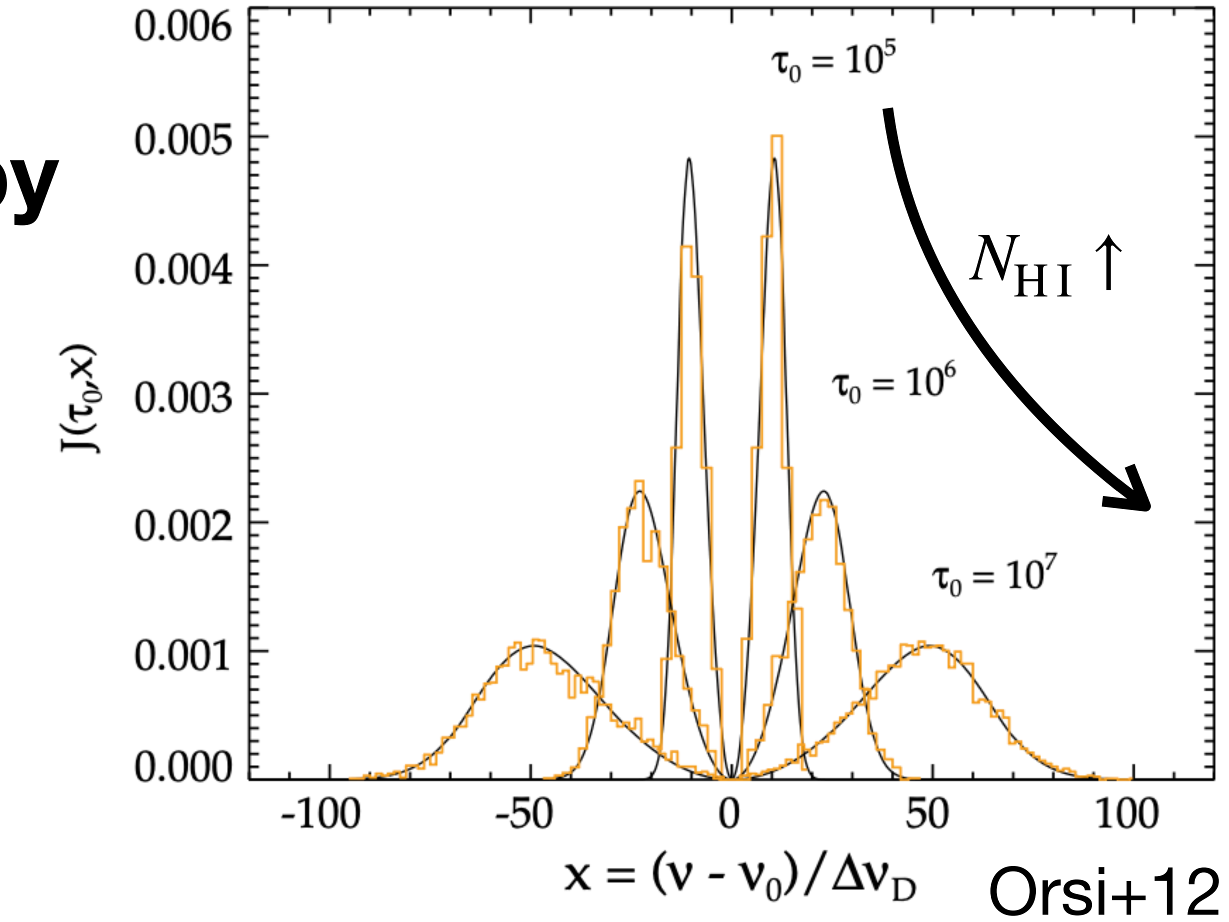
Characteristic line profile of Lyα



Dijkstra+17

Lyα profile determined by

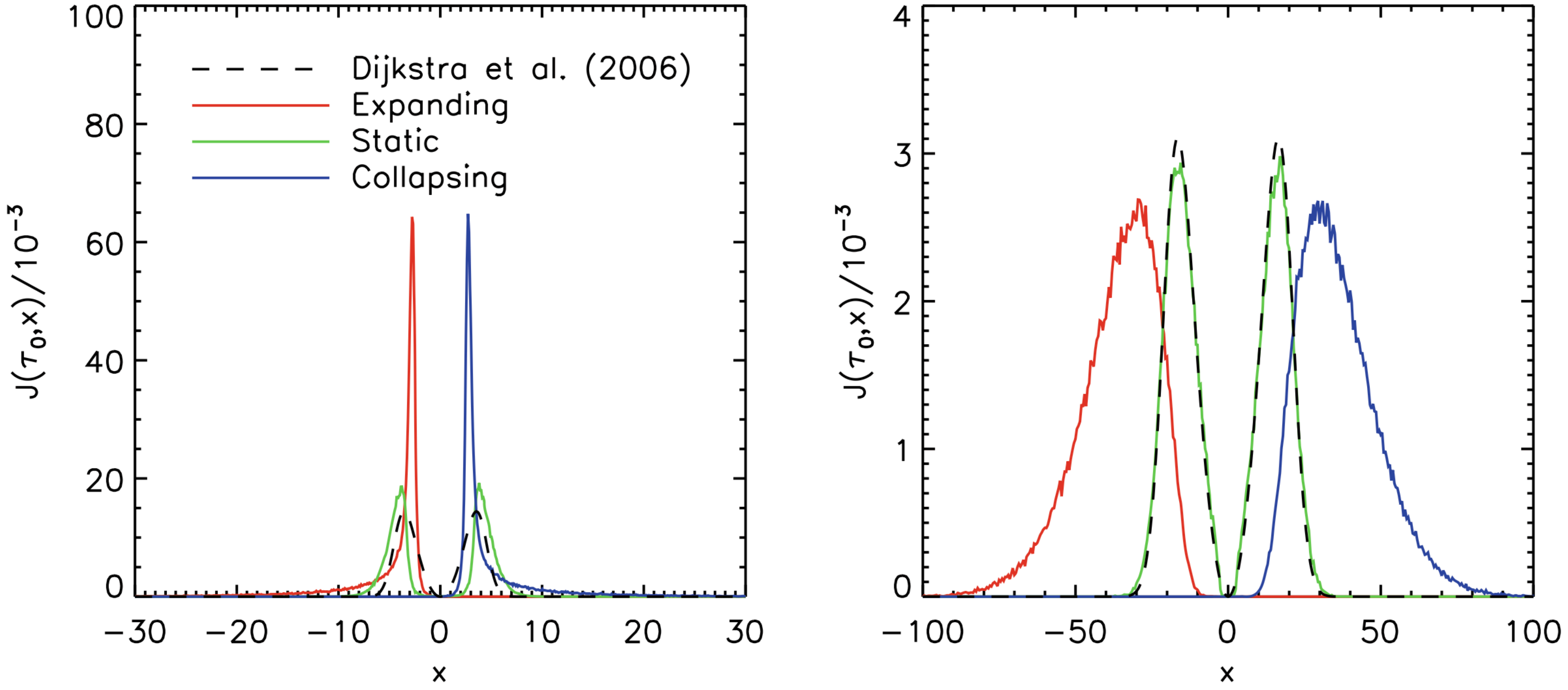
- HI column density
- Gas kinematics



Orsi+12

For Lyα photon to escape a dense medium, it should

- Spatially diffuse away from the dense environment
- Shift its frequency away from the line center

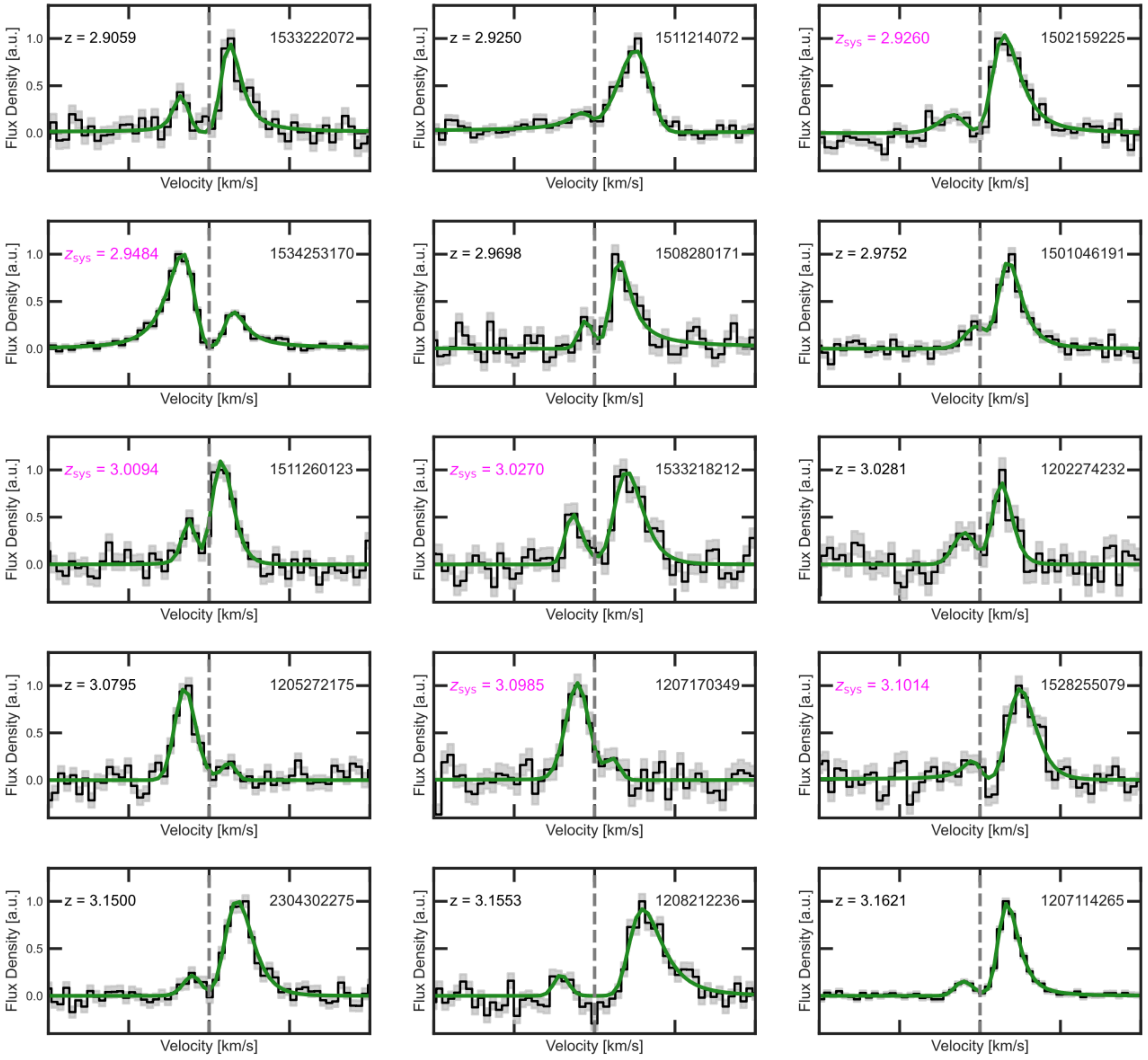


Normalized frequency

Laursen+09a

Diversity in the observed Lyα profiles

MAGPI survey



Mukherjee+25

MXDF

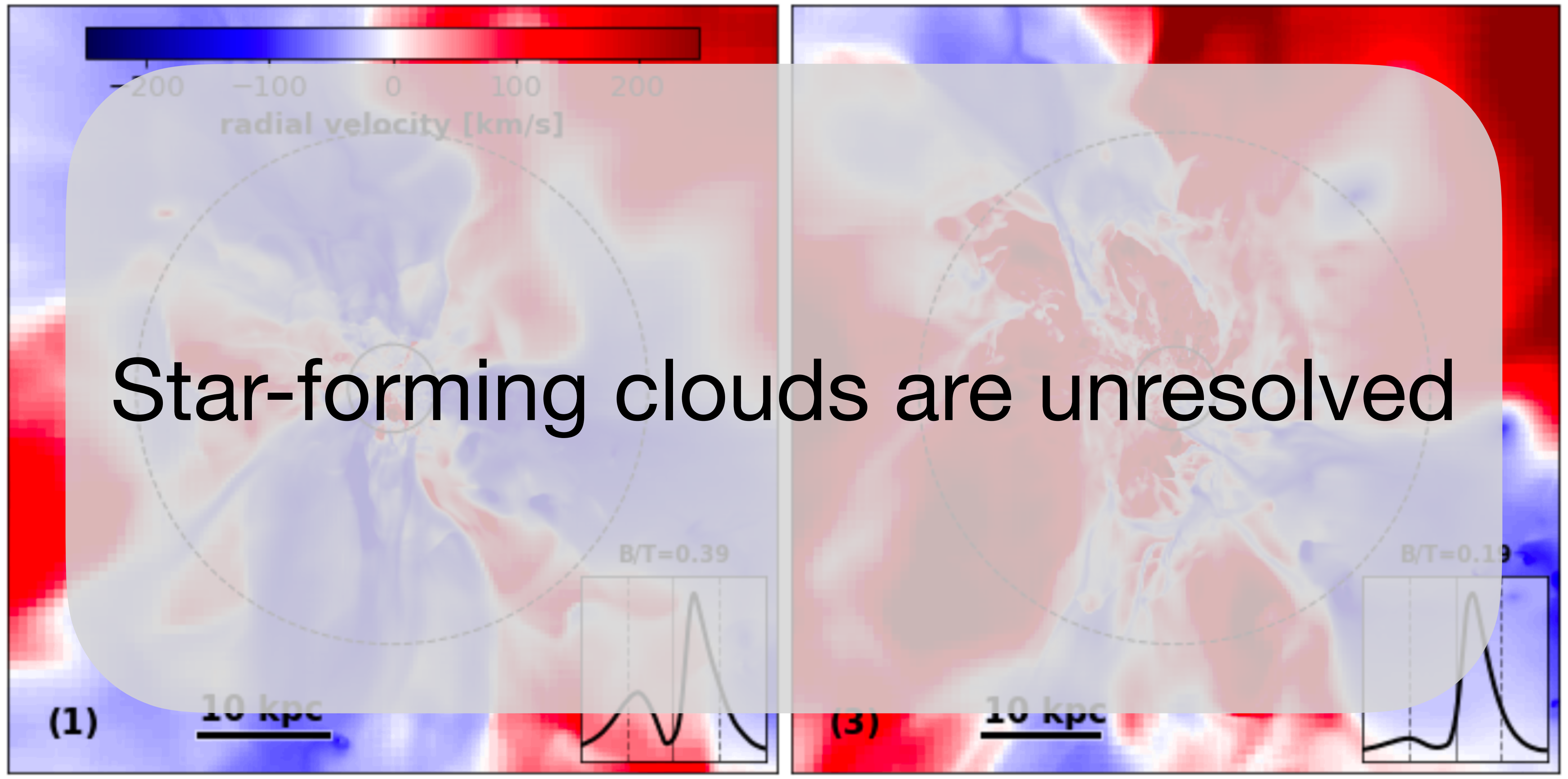
	GOLD	SILVER	BRONZE	Total
Single-peak	190	8	–	198 (41%)
Double-peaks	210	28	10	248 (52%)
Triple-peaks	19	2	1	22 (5%)
No-peak	–	–	–	9 (2%)
Total	419 (88%)	38 (8%)	11 (2%)	477

Vitte+25

- Lyα profiles exhibit diverse shapes
- Predominantly single- or double-peaked

Lyα emission from hydrodynamic simulations

Large-scale
(Cosmological zoom-in simulation)

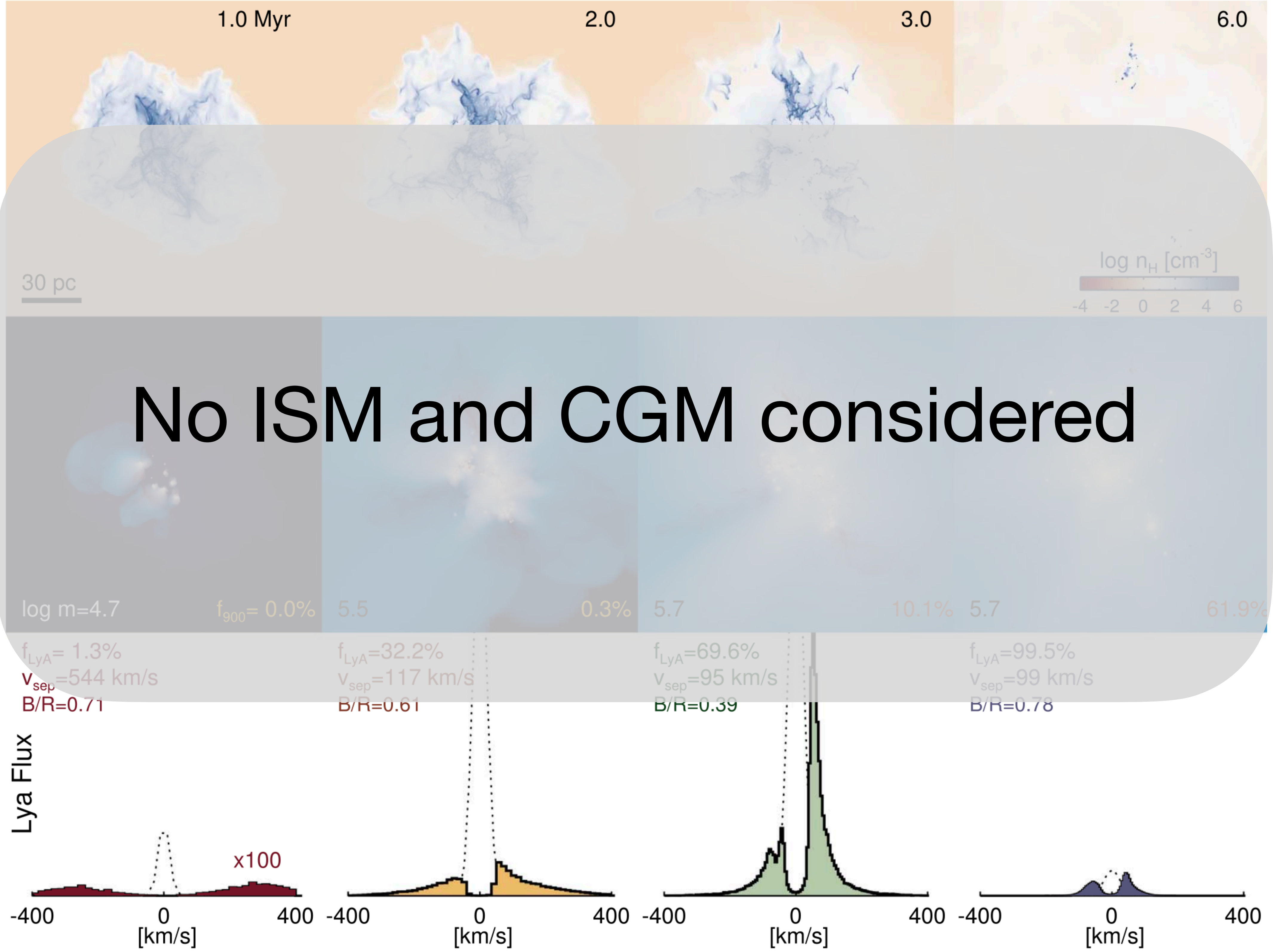


Star-forming clouds are unresolved

$\Delta x_{\mathrm{min}} \approx 14\,\mathrm{pc}$

Blaizot+23

Small-scale
(GMC simulation)

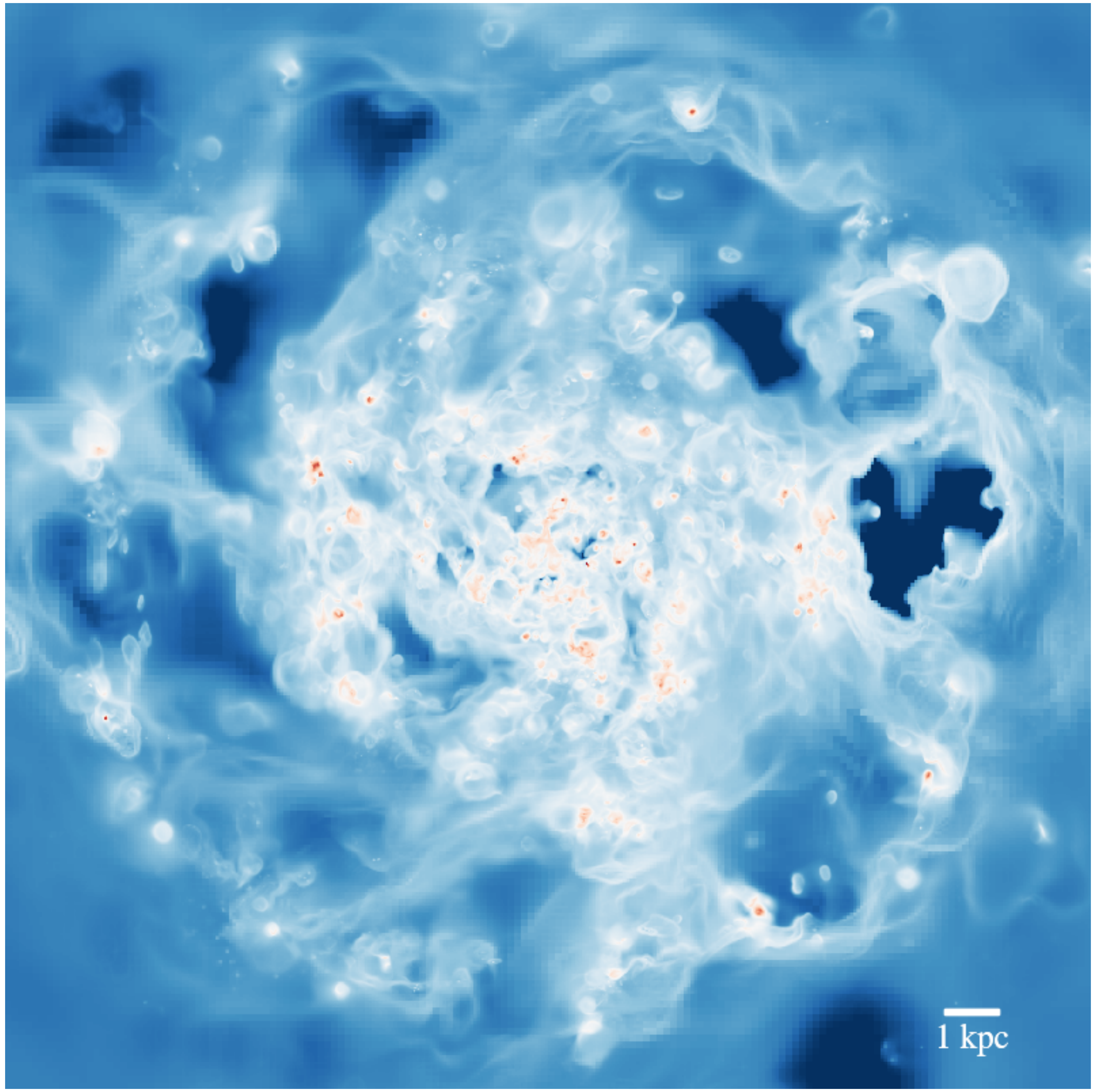


No ISM and CGM considered

$\Delta x_{\mathrm{min}} \approx 0.02 - 0.08\,\mathrm{pc}$

Kimm+22

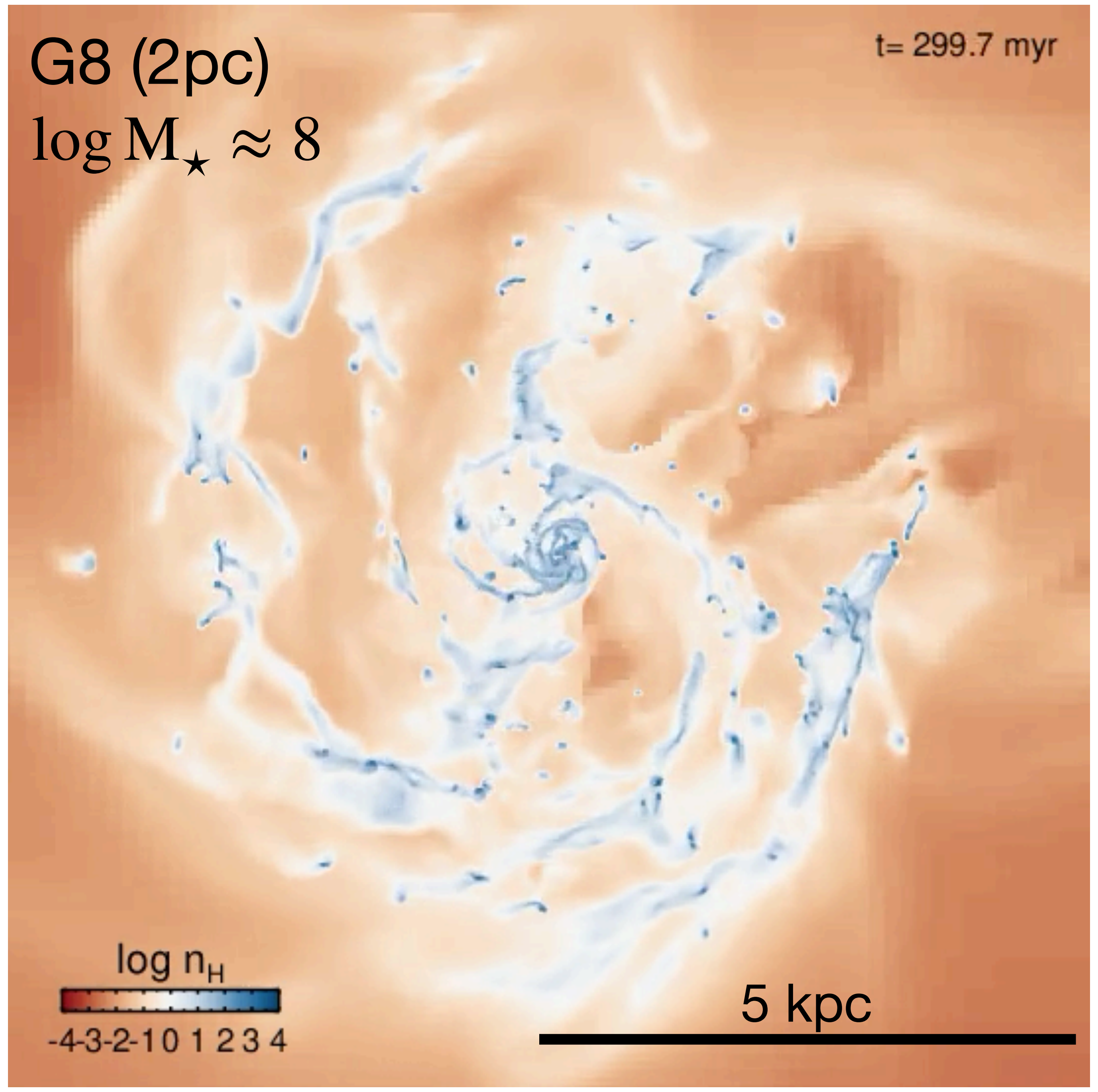
Multi-scale analysis of Lyα radiative transfer

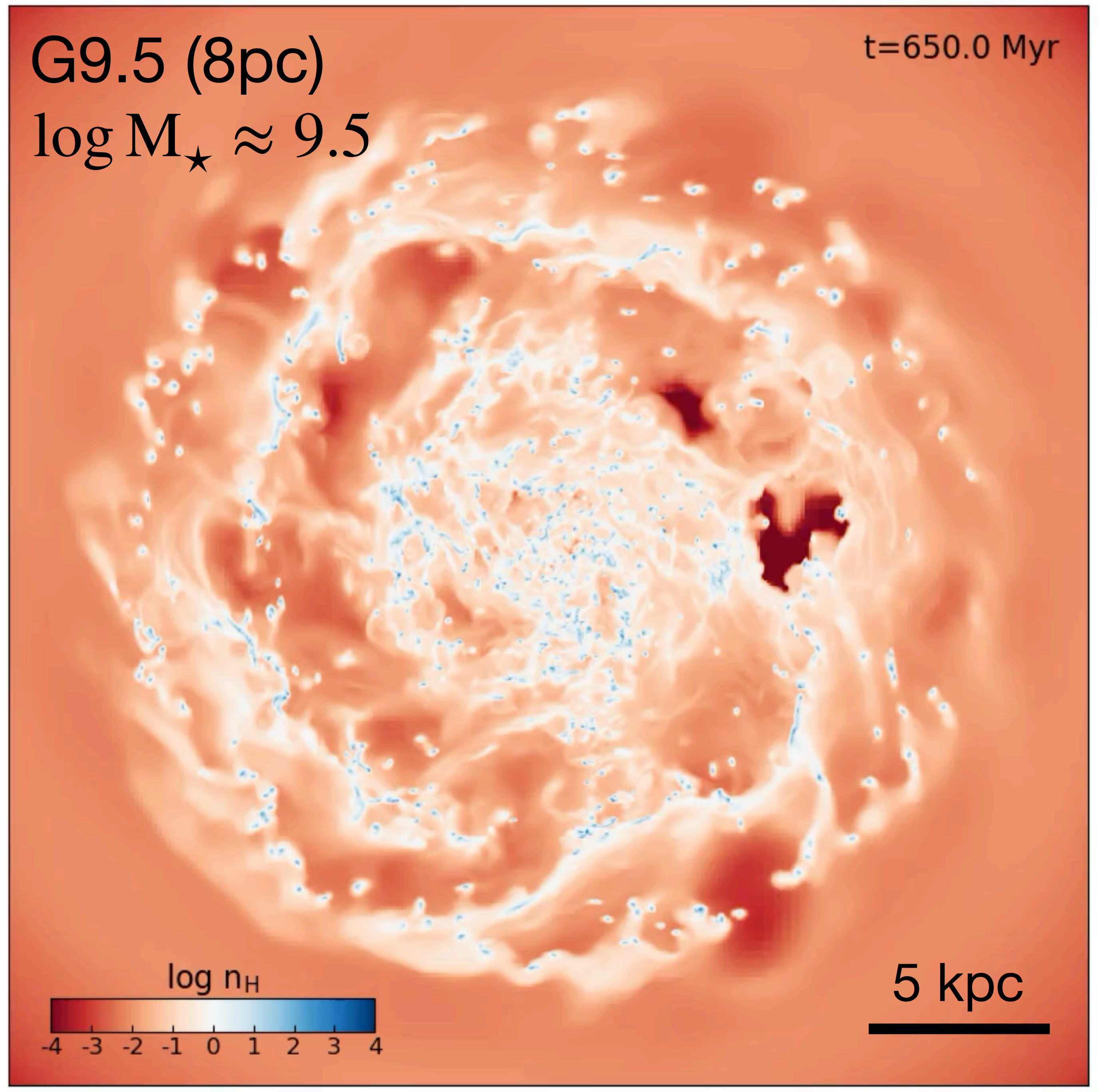


Where do Lyα photons originate?

- Star-forming regions?
- Diffuse Ionized Gas?

Do Lyα photons with different spatial origins exhibit distinct profiles?





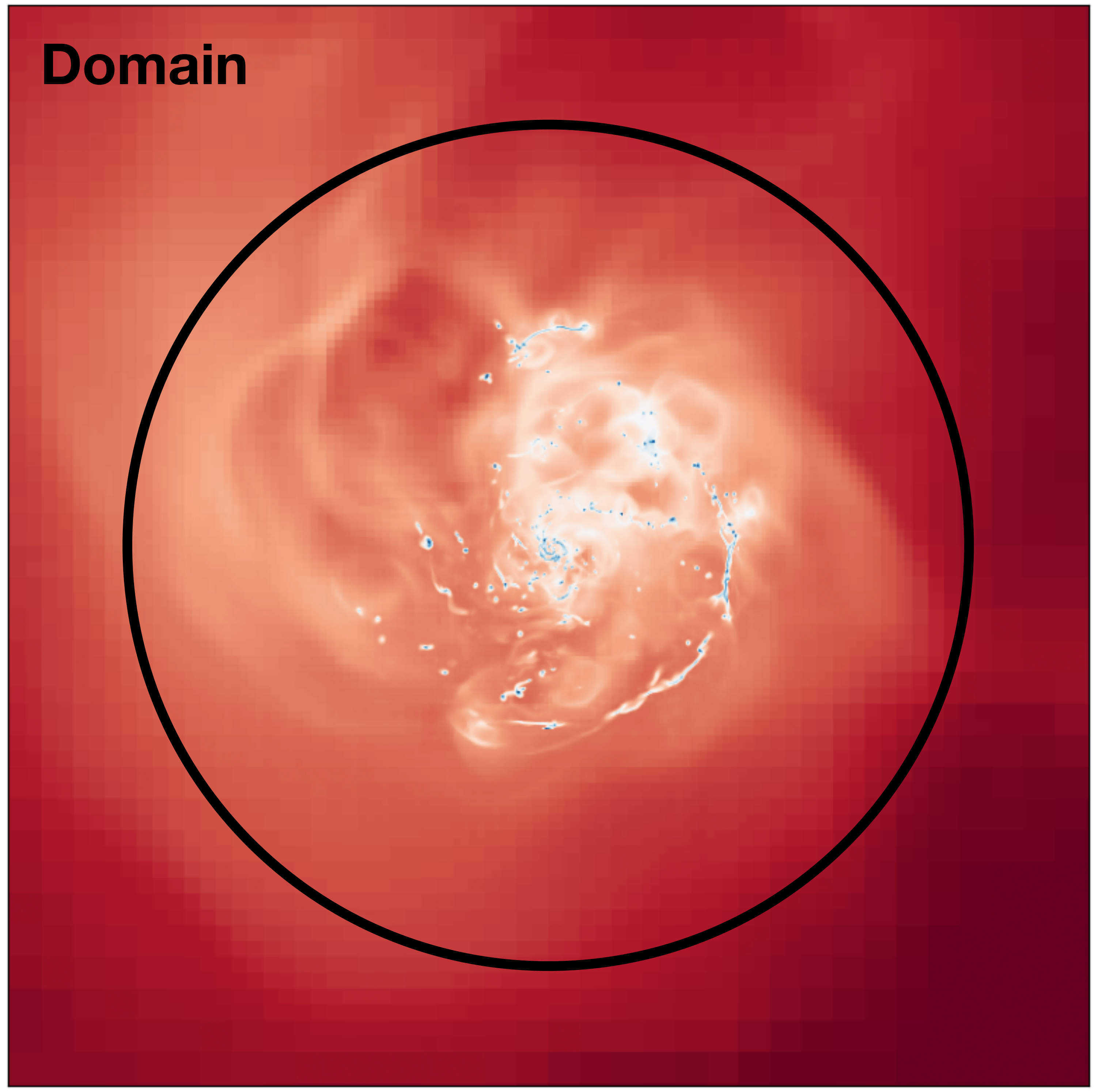
Idealized disk galaxy simulations

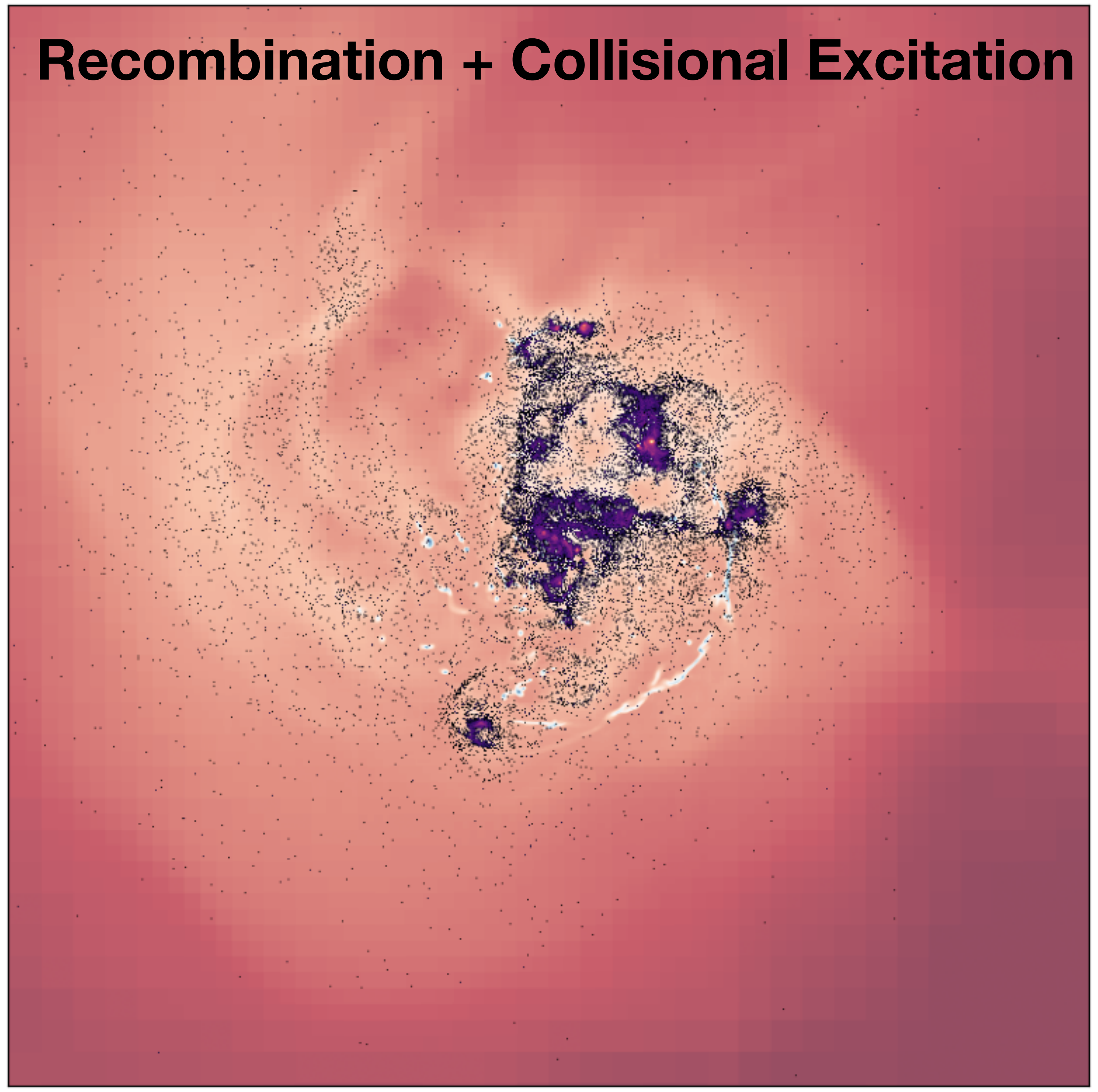
Model	M_{halo} $[M_\odot]$	$M_\star$ $[M_\odot]$	R_{vir} [kpc]	f_{gas}	$\langle Z_{disk} \rangle$	Δx_{min} [pc]
G8	10^{10}	4×10^8	42	0.5	0.002	2.2
G9.5	3×10^{11}	3×10^9	130	0.3	0.34	7.8

- Radiation-hydrodynamic simulation code, RAMSES-RT (Teyssier 02, Rosdahl & Teyssier 15)
- Sink-particle based star-formation model (Bleuler & Teyssier 14) → Cheonsu's and Daniel's Talk!
- Feedback channels: Radiation & Type II SN feedback (Kimm & Cen 14)
- Non-equilibrium chemistry (H_2, H I, H II, He I, He II, He III, e)

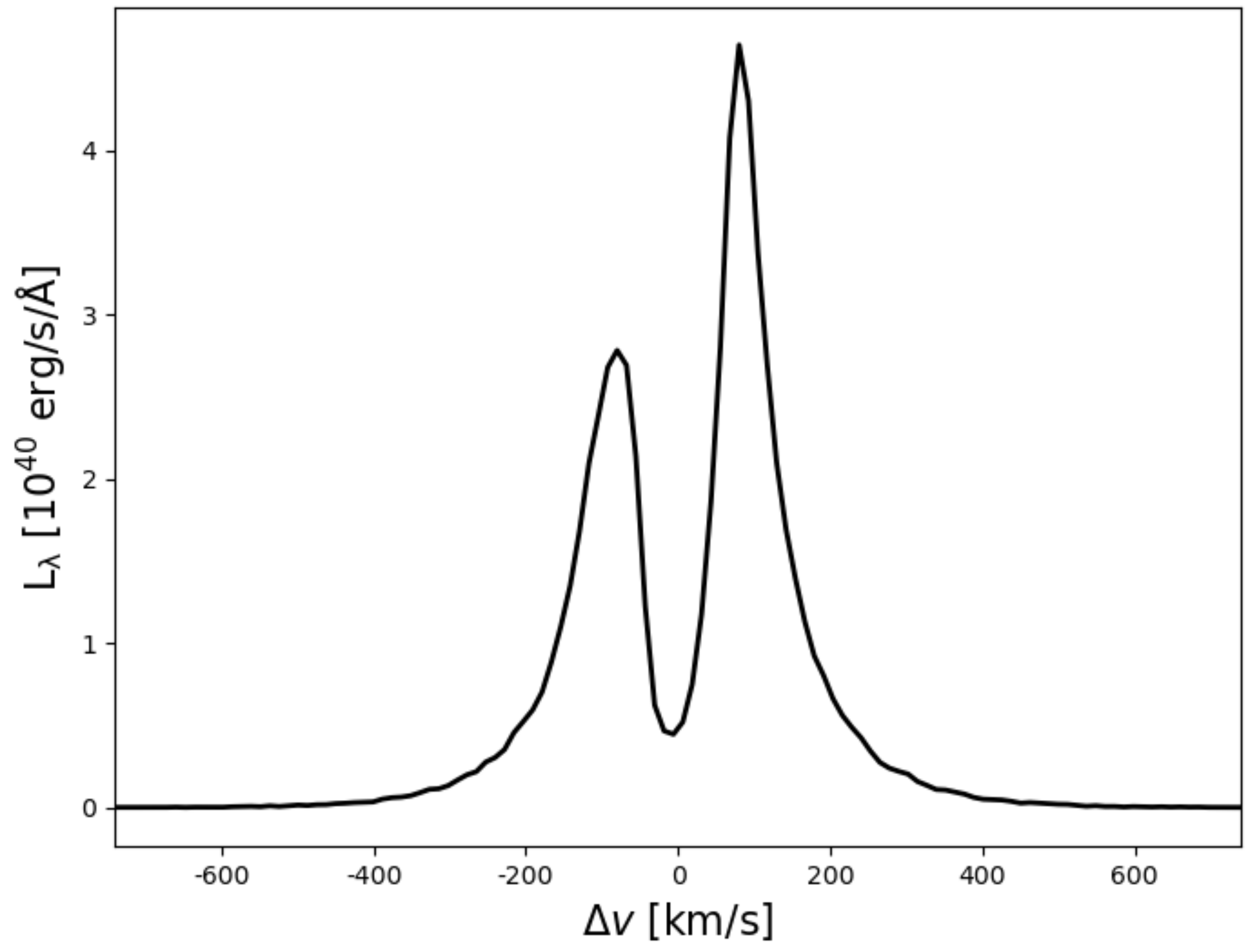
Monte-Carlo Radiative Transfer code

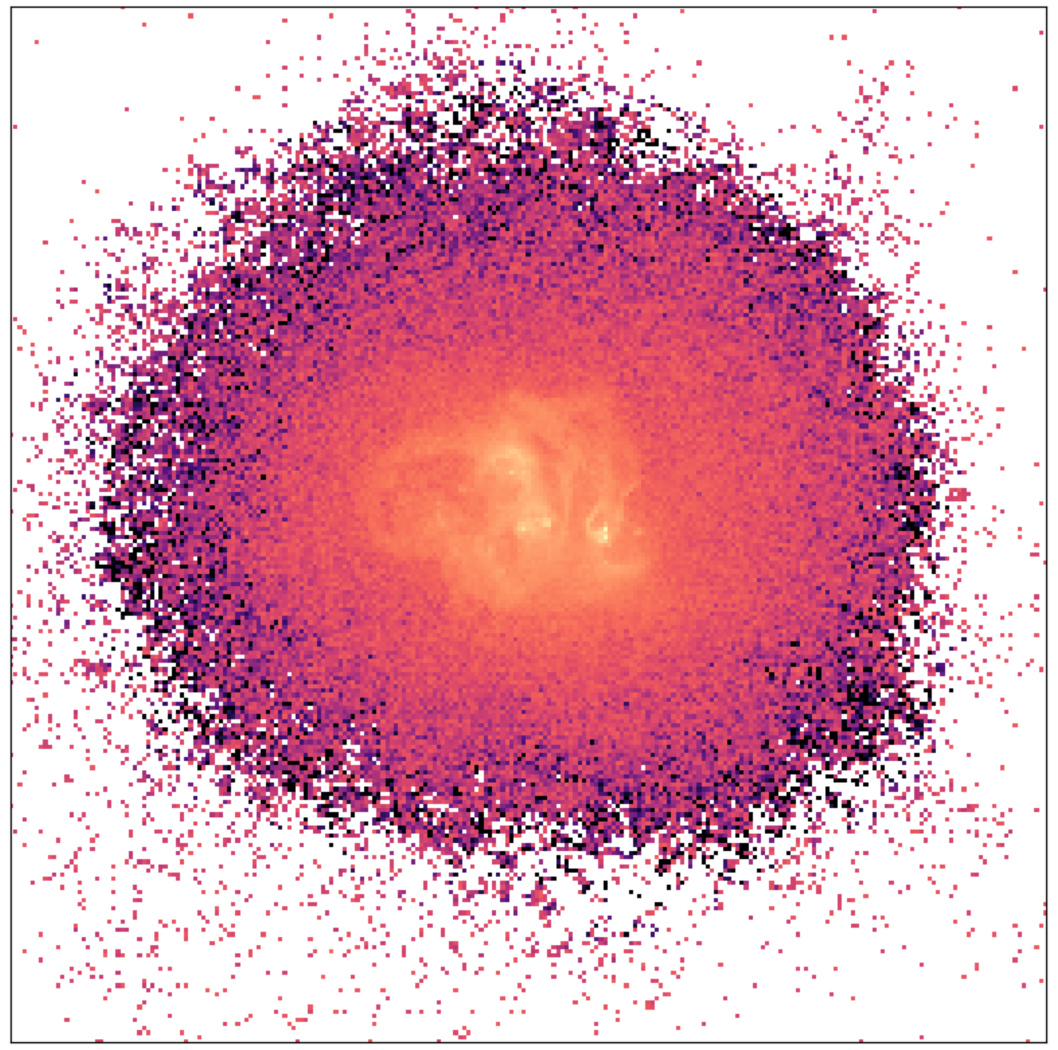
RASCAS (Michel-Dansac+20)



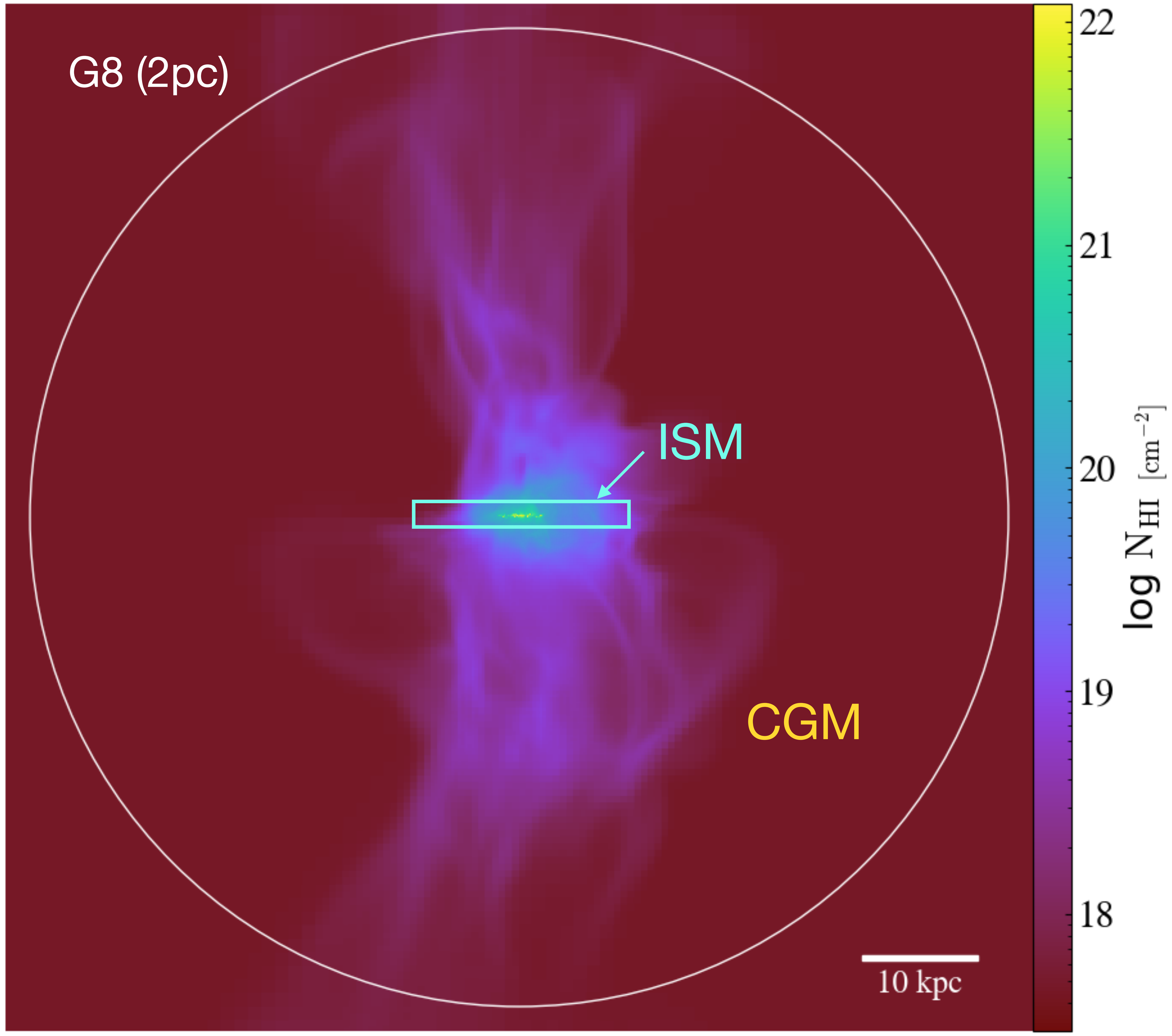


Radiative Transfer





Definition of scales



Lyα clumps

- Regions with clustered Lyα emission, $r \lesssim 100$ pc
- Identified using *DBSCAN*

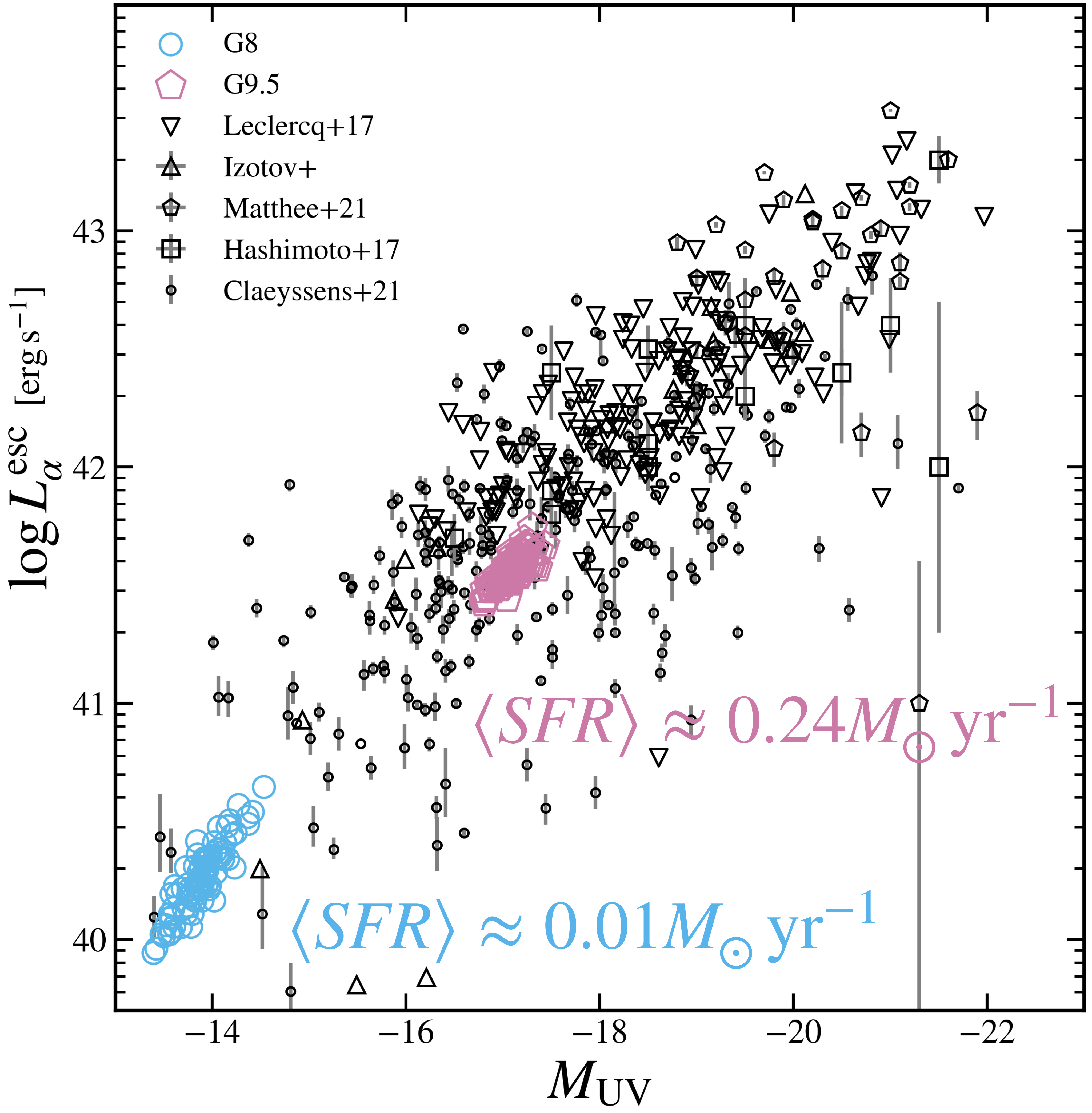
Interstellar Medium (ISM)

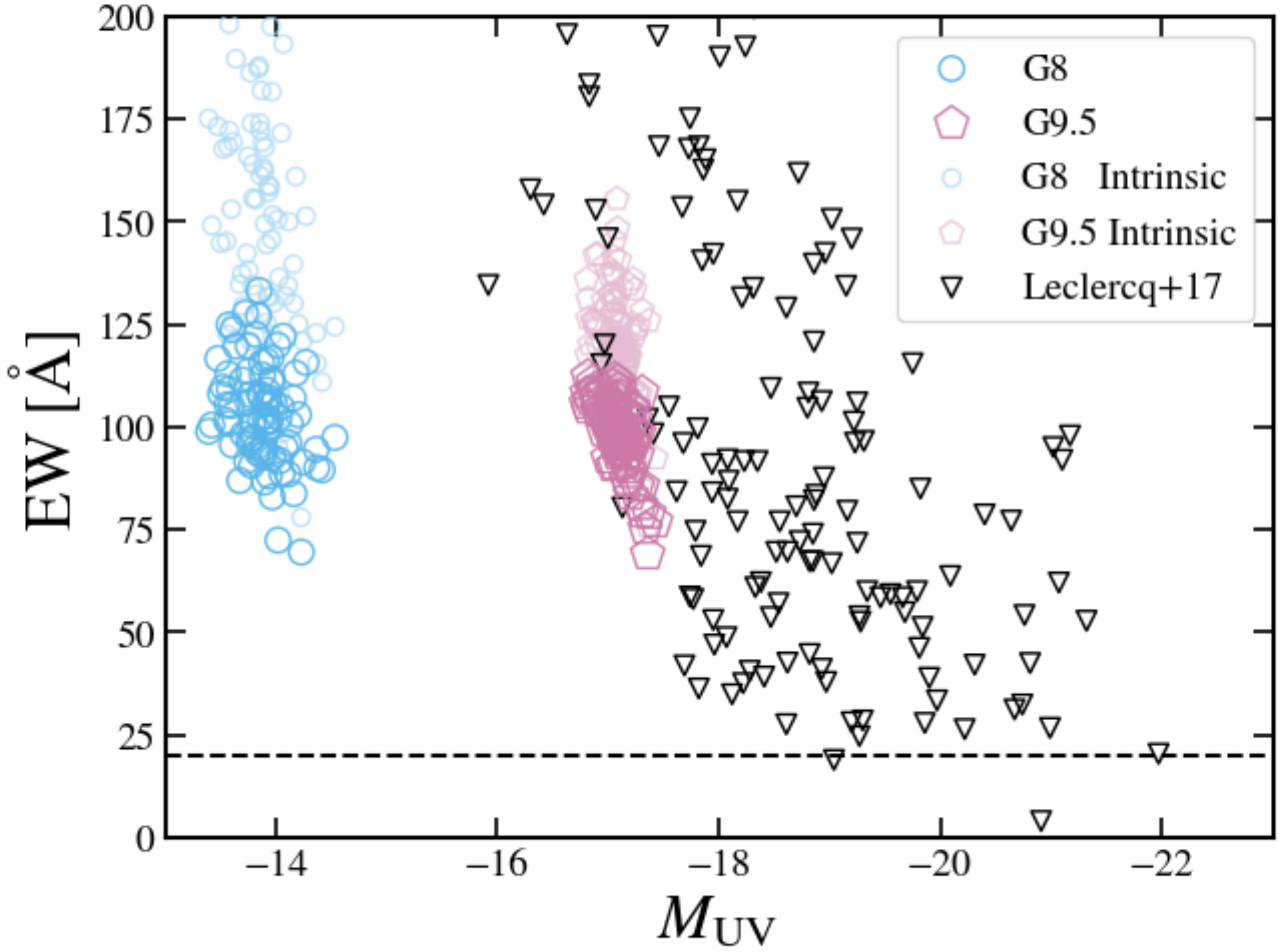
- Cylinder, $r \leq 0.2R_{\rm vir}$ & $h \leq 10 \times H$

Circumgalactic Medium (CGM)

- Outside the disk, and $r \leq R_{\rm vir}$

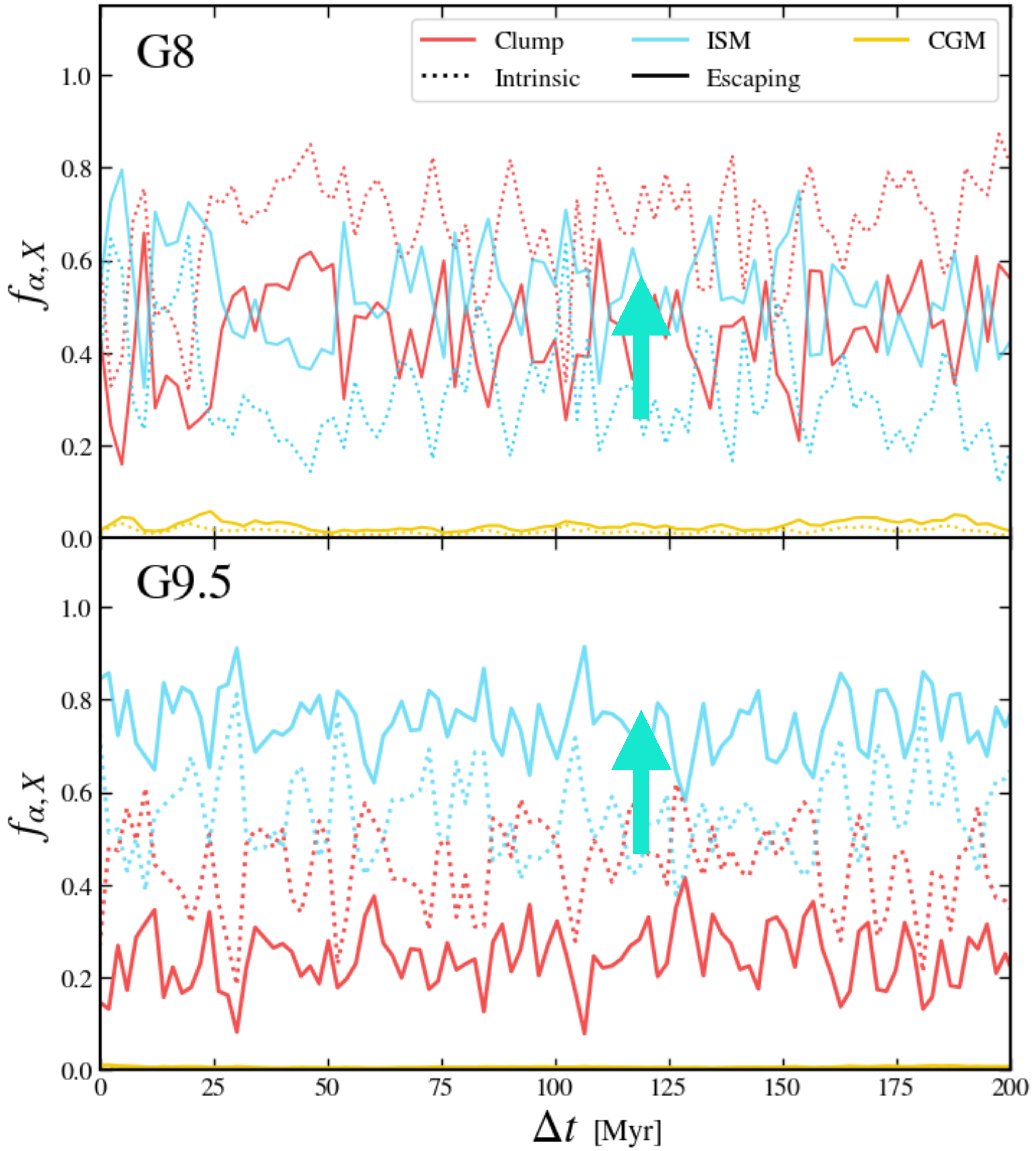
G8 and G9.5 are Lyα Emitters





- Good agreement with observations
- Consistently lie in LAE definition (EW > 20Å)

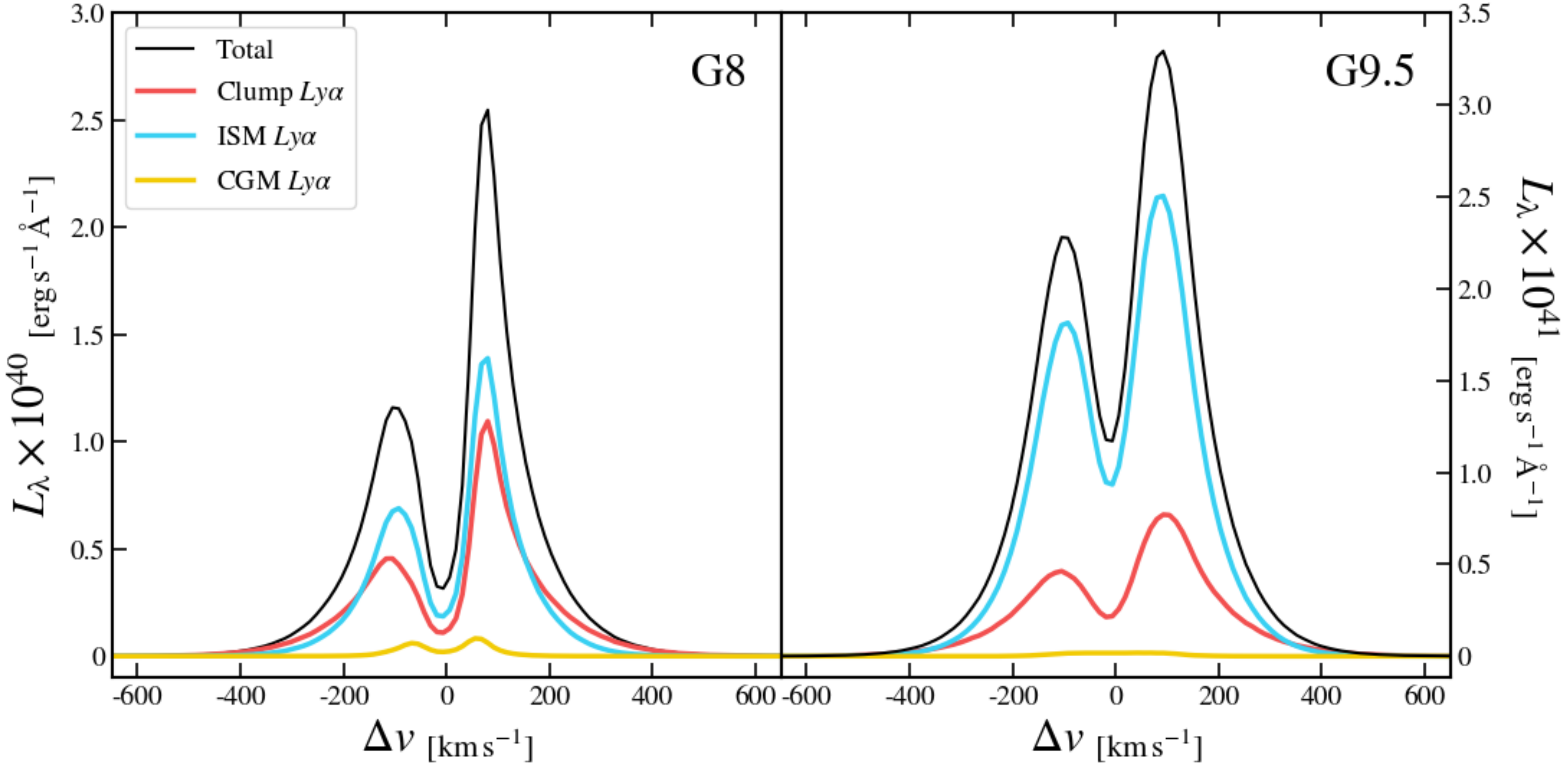
Spatial origin of Lyα emission

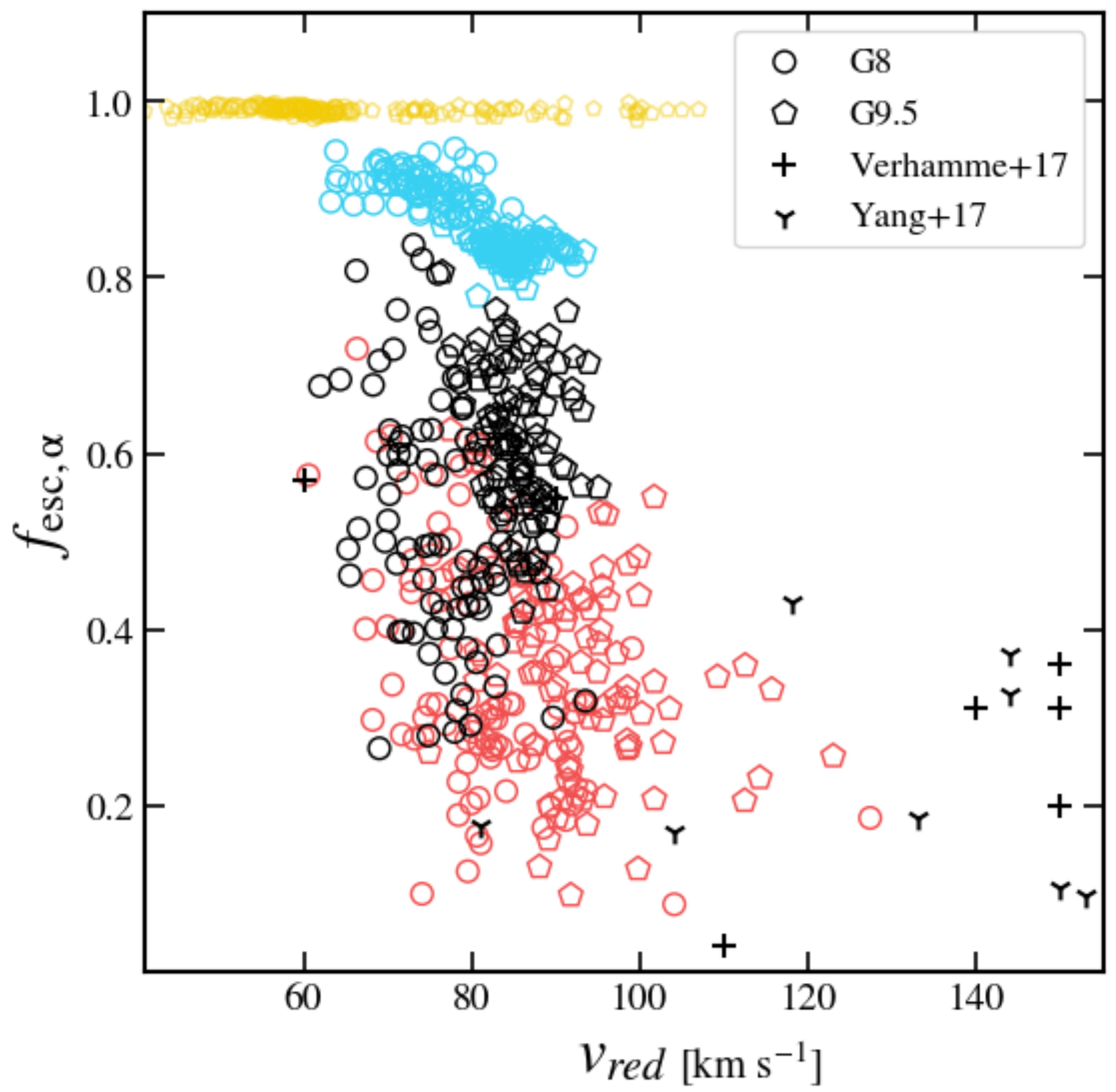


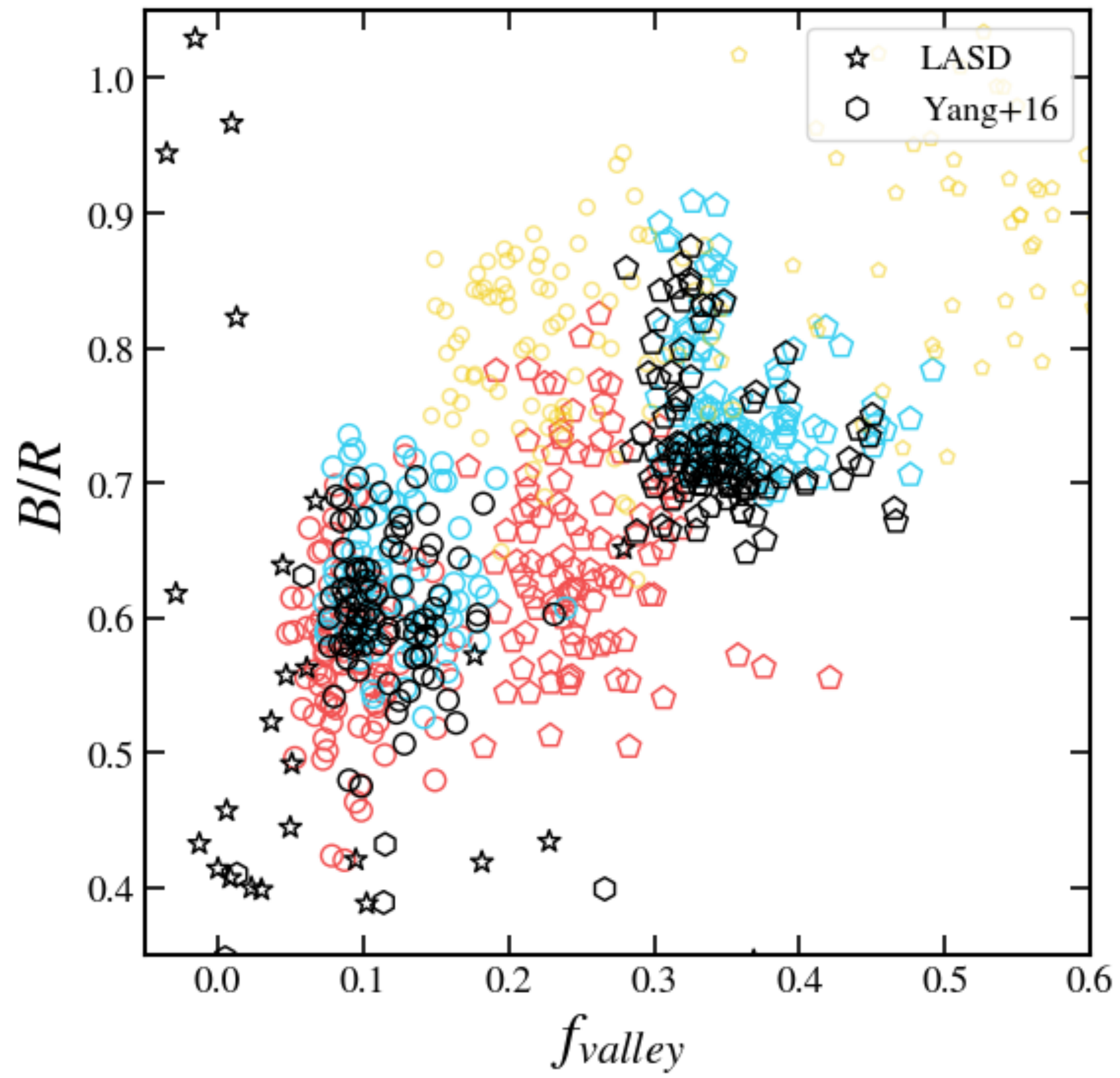
	G8		G9.5	
	intrinsic	escaping	intrinsic	escaping
$f_{\alpha,\mathrm{Clump}}$ [%]	67.2 ± 12.2	44.1 ± 11.1	44.1 ± 9.4	24.2 ± 6.6
$f_{\alpha,\mathrm{ISM}}$ [%]	31.3 ± 11.8	53.2 ± 10.8	55.5 ± 9.3	75.2 ± 6.6
$f_{\alpha,\mathrm{CGM}}$ [%]	1.4 ± 0.6	2.7 ± 1.0	0.4 ± 0.1	0.6 ± 0.1

- $f_{\alpha,X} \equiv L_X/L_{tot}$, $X \in$ {Clump, ISM, CGM}
- Clump Lyα : significant source intrinsically
- ISM Lyα : dominant source of the escaping luminosity
- CGM Lyα : negligible (Caution!)

Distinct profiles depending on the spatial origin





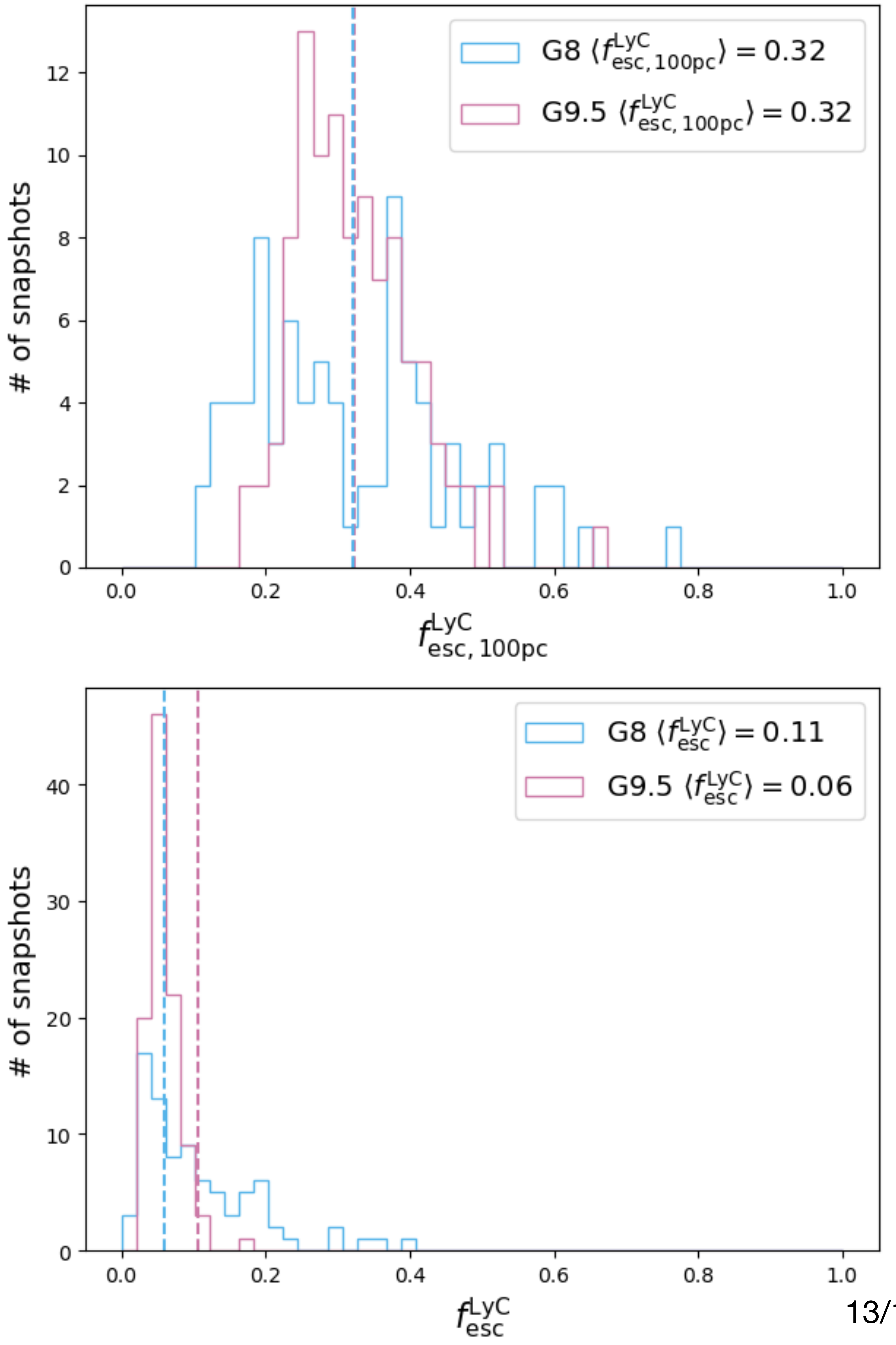


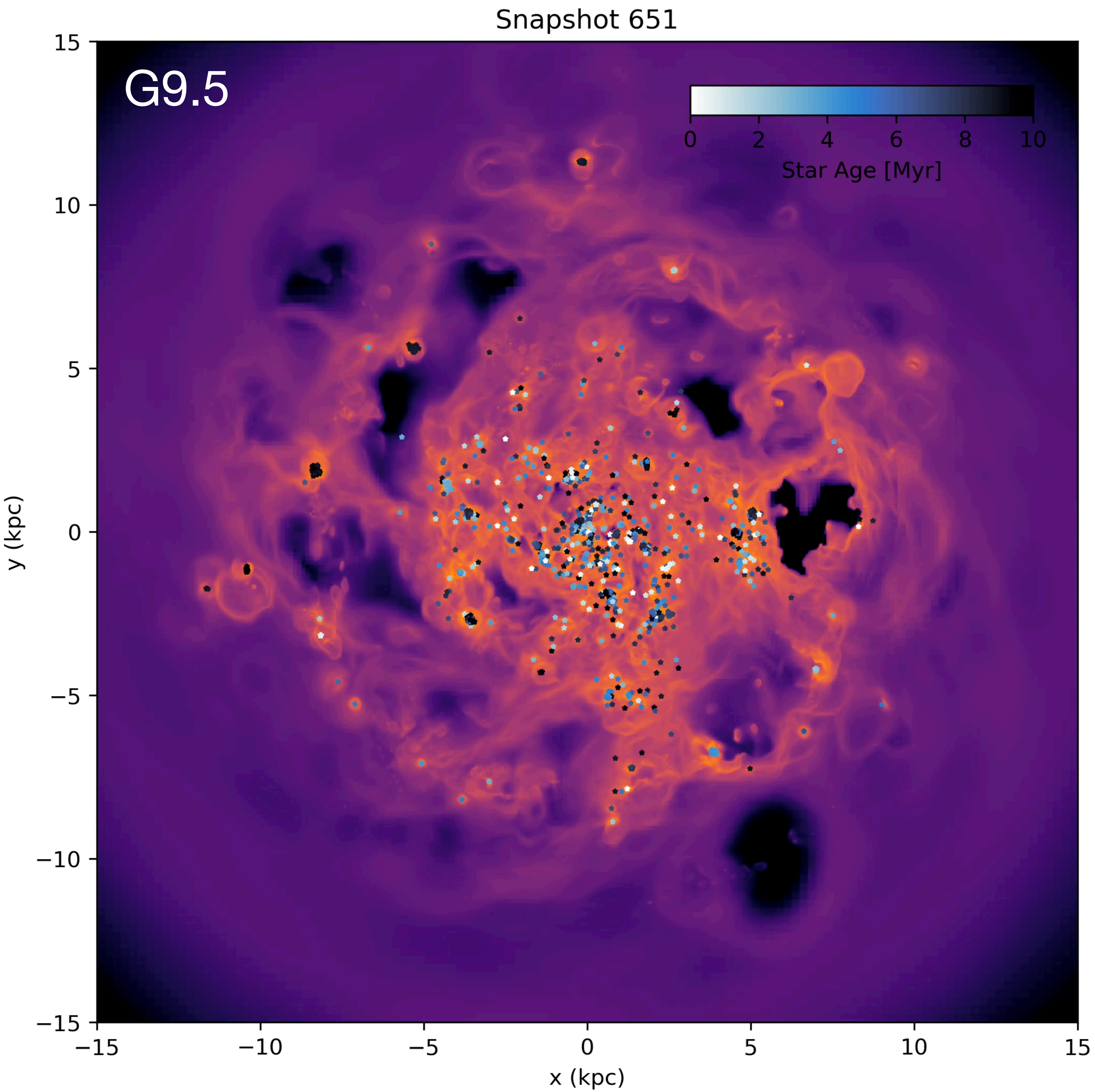
Clump Lyα : $f_{esc,\alpha} \uparrow$, $B/R \downarrow$, $f_{valley} \downarrow$

ISM Lyα : $f_{esc,\alpha} \downarrow$, $B/R \uparrow$, $f_{valley} \uparrow$

Why does G9.5 has a larger ISM contribution?

- Recombination also dominates ISM Lyα emission in G9.5
- Scenario: Thicker ISM of G9.5 more efficiently absorb ionizing photons
- Yes, but not sufficient to explain the intrinsic dominance of ISM emission over clump emission





Young stars born in diffuse gas

- Sink-particle used to makes stars survive
- Wandering sink particle form 1-2 star particles,
- making up $\gtrsim 30\,\%$ young stars outside the gas clumps

Summary

1. **Where do Lyα photons originate?**

   - Predominantly from the star-forming regions (clumps) & diffuse ISM
   - Diffuse ISM emission can be a dominant source!

2. **Clump, ISM, and CGM Lyα exhibit distinct profiles**

   - Clump Lyα: Low escape fraction, red-peak dominant profile, low emission near line-center
   - ISM Lyα: high escape fraction, symmetric profile, high emission near line-center
   - CGM Lyα: faint, but can be model dependent (Caution!) -> High-resolution Cosmological Zoom-in Simulation