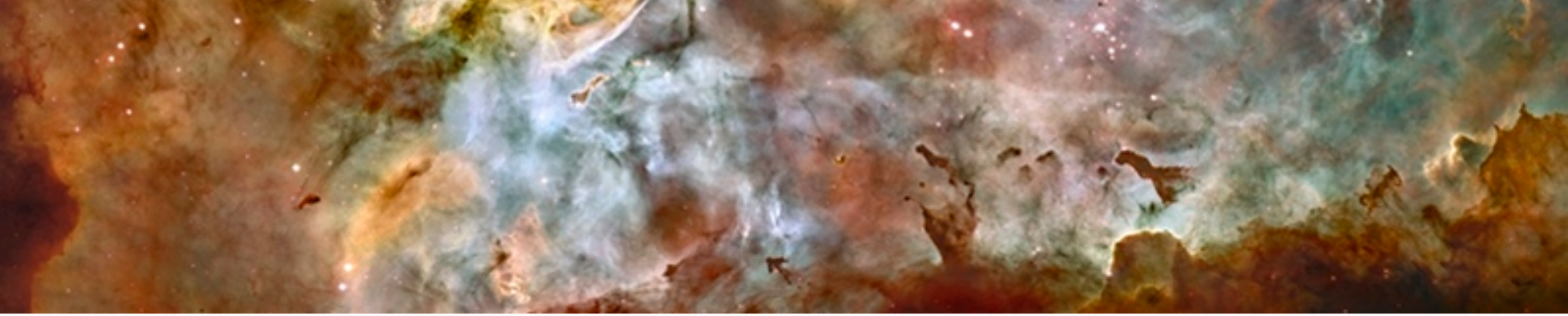

Simulating Lyα Sources in the Epoch of Reionization

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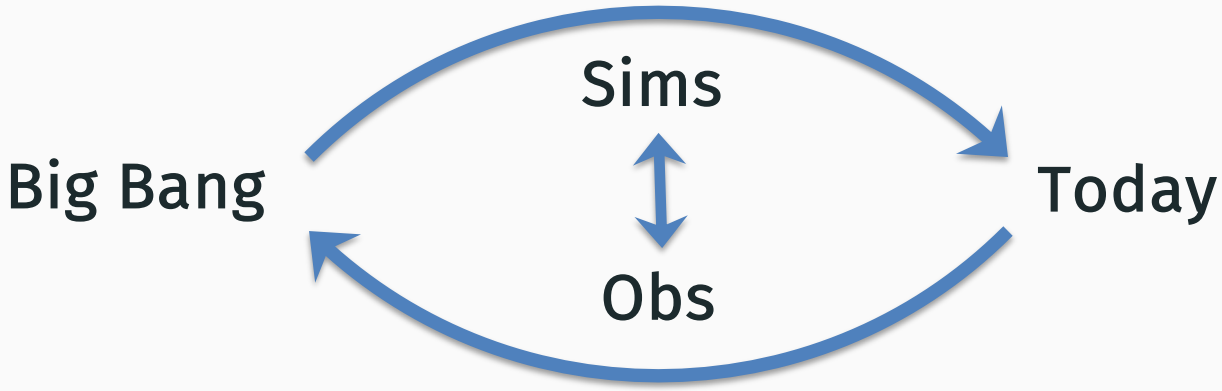
Sakura Cosmic Lyman-Alpha Workshop

March 30, 2018 www.as.utexas.edu/~asmith

THE UNIVERSITY OF TEXAS AT AUSTIN

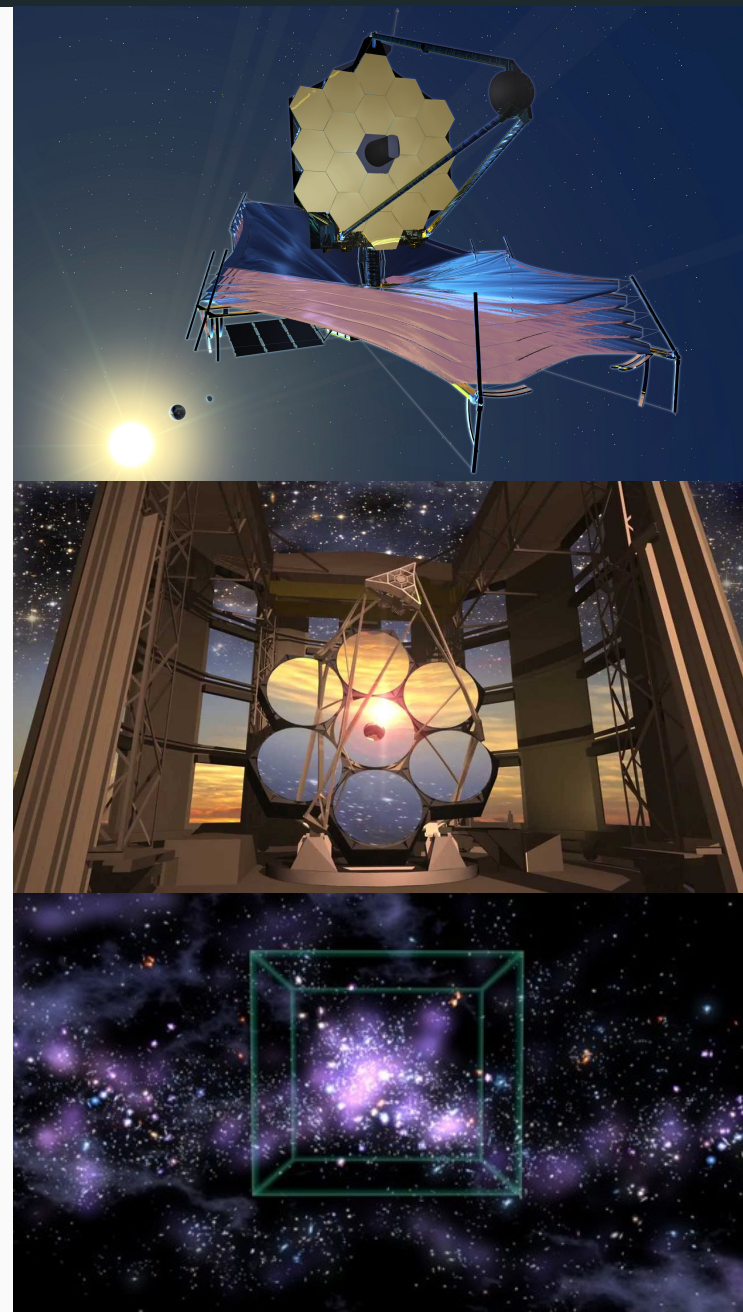
NSF Graduate Research Fellowship Program

TALK OVERVIEW

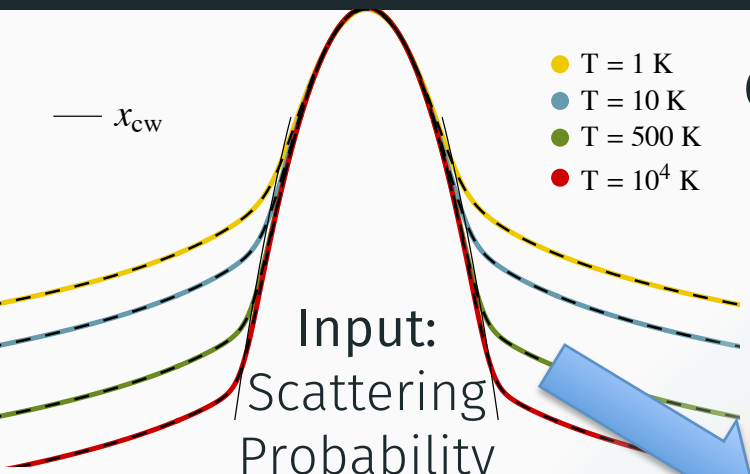


Computer simulations connect what can be directly seen with what is ultimately powering celestial sources. We weave the snapshots accessible to observations into a continuous tapestry of cosmic evolution.

- Frontiers in Lyman-alpha radiative transfer
- Resonant Discrete Diffusion Monte Carlo (rDDMC)
- Radiation hydrodynamics and zoom-in simulations



(SOME!) FRONTIERS IN MULTI-SCALE LYMAN-ALPHA RADIATIVE TRANSFER



Input: Scattering Probability

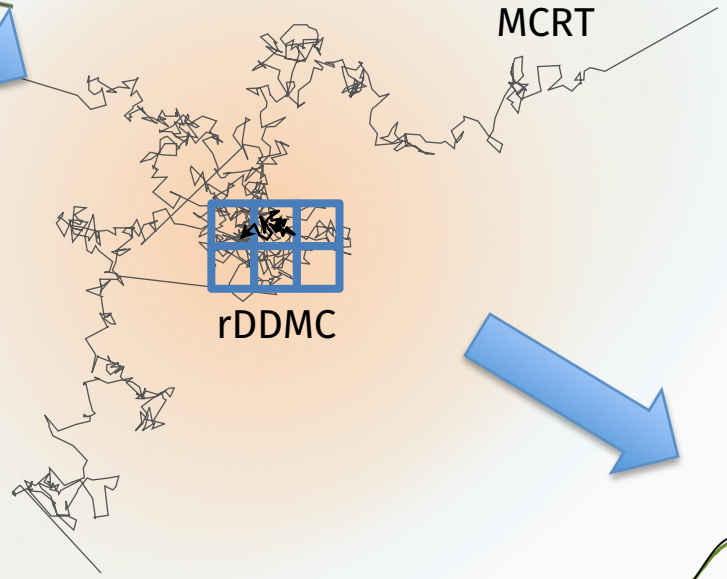
Cosmic Lyα Transfer code (COLT)

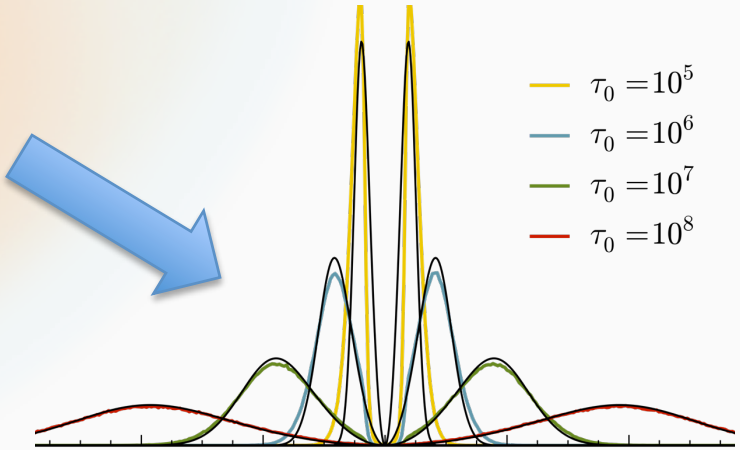
- Monte Carlo Methodology
- Parallel: MPI + OpenMP

Empirical Models (Shells/Clumps)

Hybrid Methods (Subgrid/Approx)

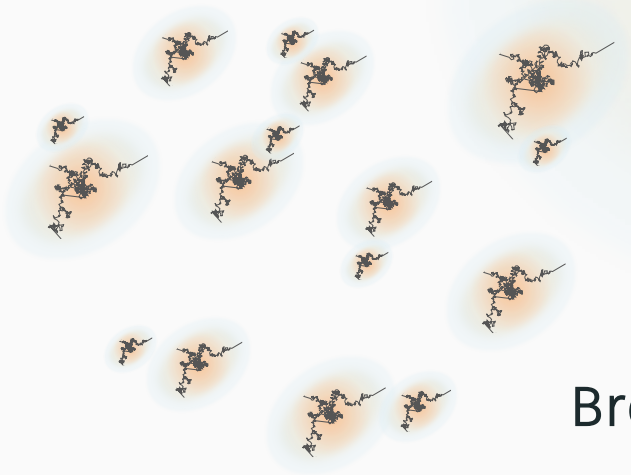
Ab Initio Approach (Cosmological etc. Galaxy Simulations)





Output: Flux vs. Frequency

Simulation-based high-z LAE surveys

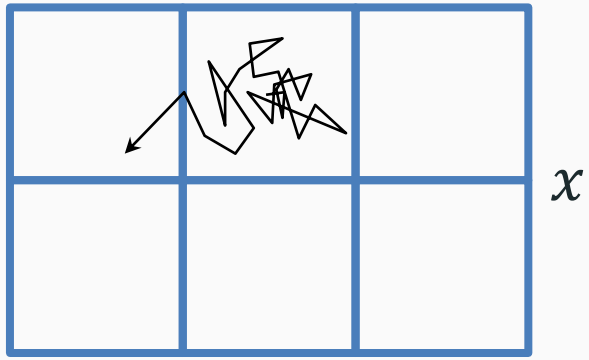


Breaking the MCRT efficiency barrier with my new resonant DDMC method

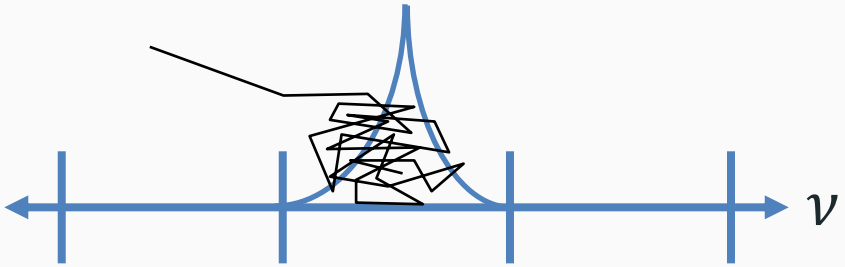
RESONANT DISCRETE DIFFUSION MONTE CARLO (rDDMC)

Discretized transfer equation leads to a Monte Carlo interpretation.

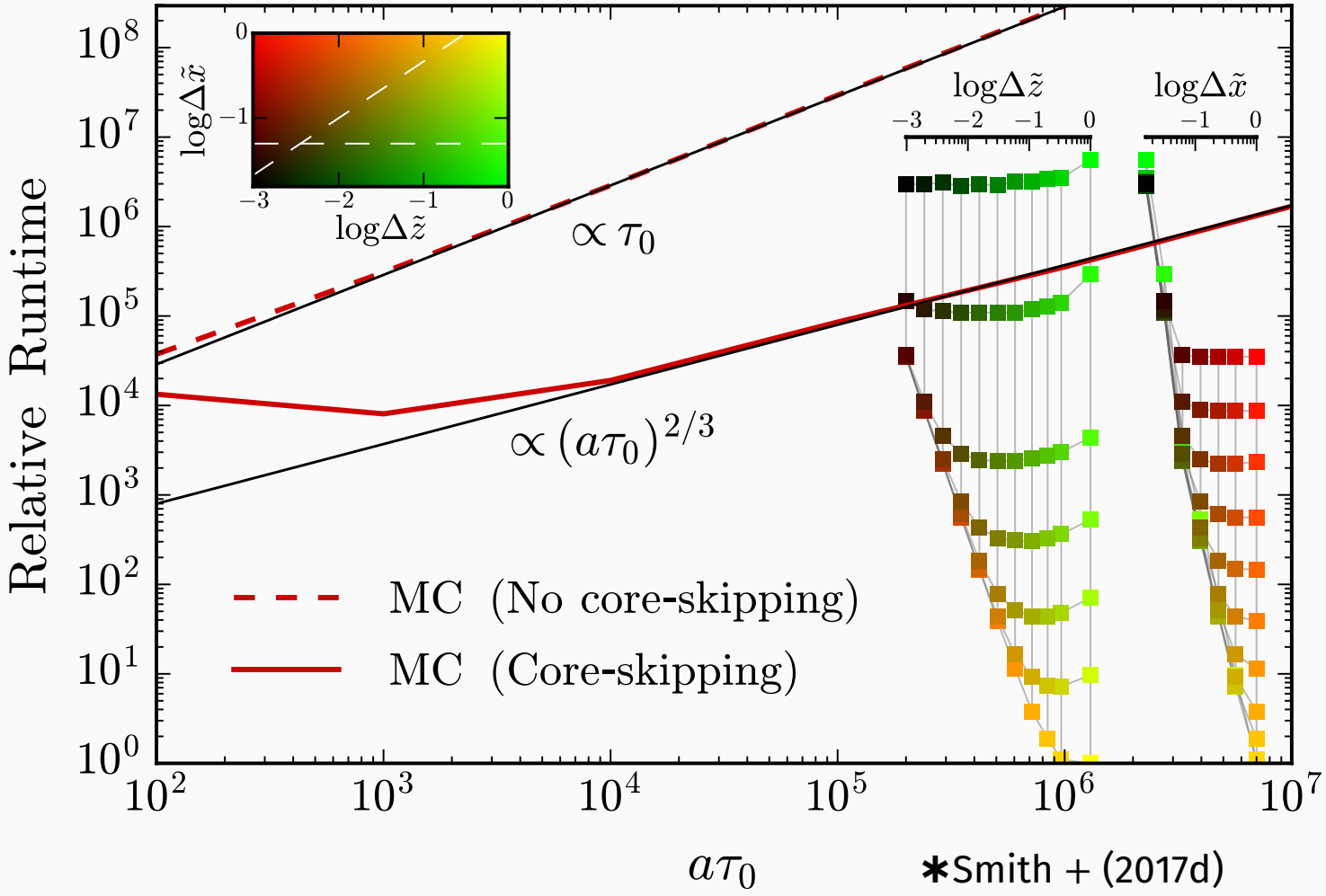
$$\frac{1}{c}\frac{\partial J}{\partial t} = \nabla \cdot \left(\frac{\nabla J}{3k}\right) + \frac{\partial}{\partial \nu}\left(\frac{k}{2}\frac{\partial J}{\partial \nu}\right)$$



Skips scatterings if $\lambda_{\rm mfp} \ll \Delta x$



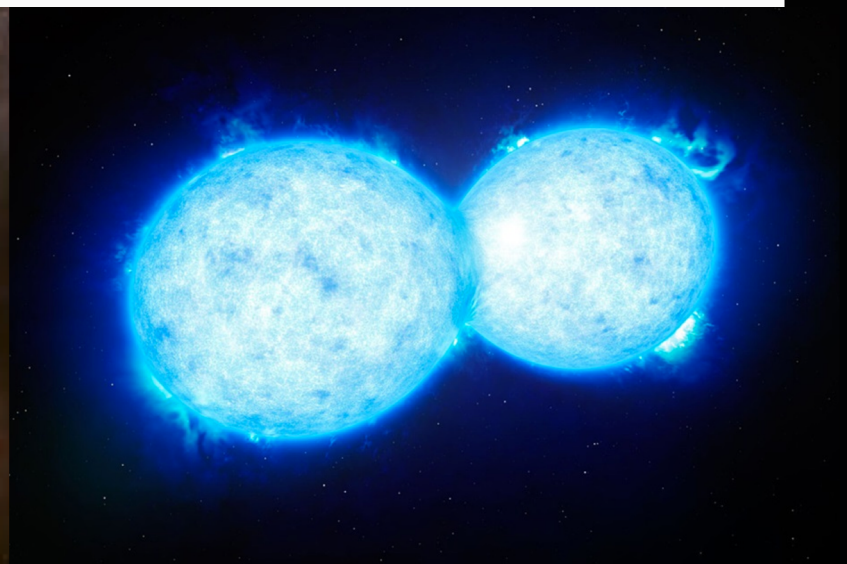
Diffusion in Space & Frequency

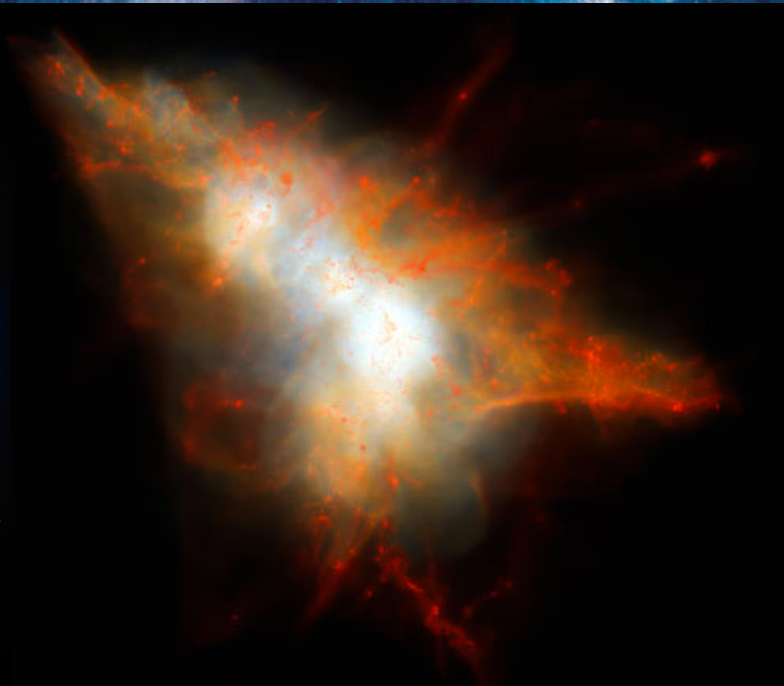


∗Smith + (2017d)

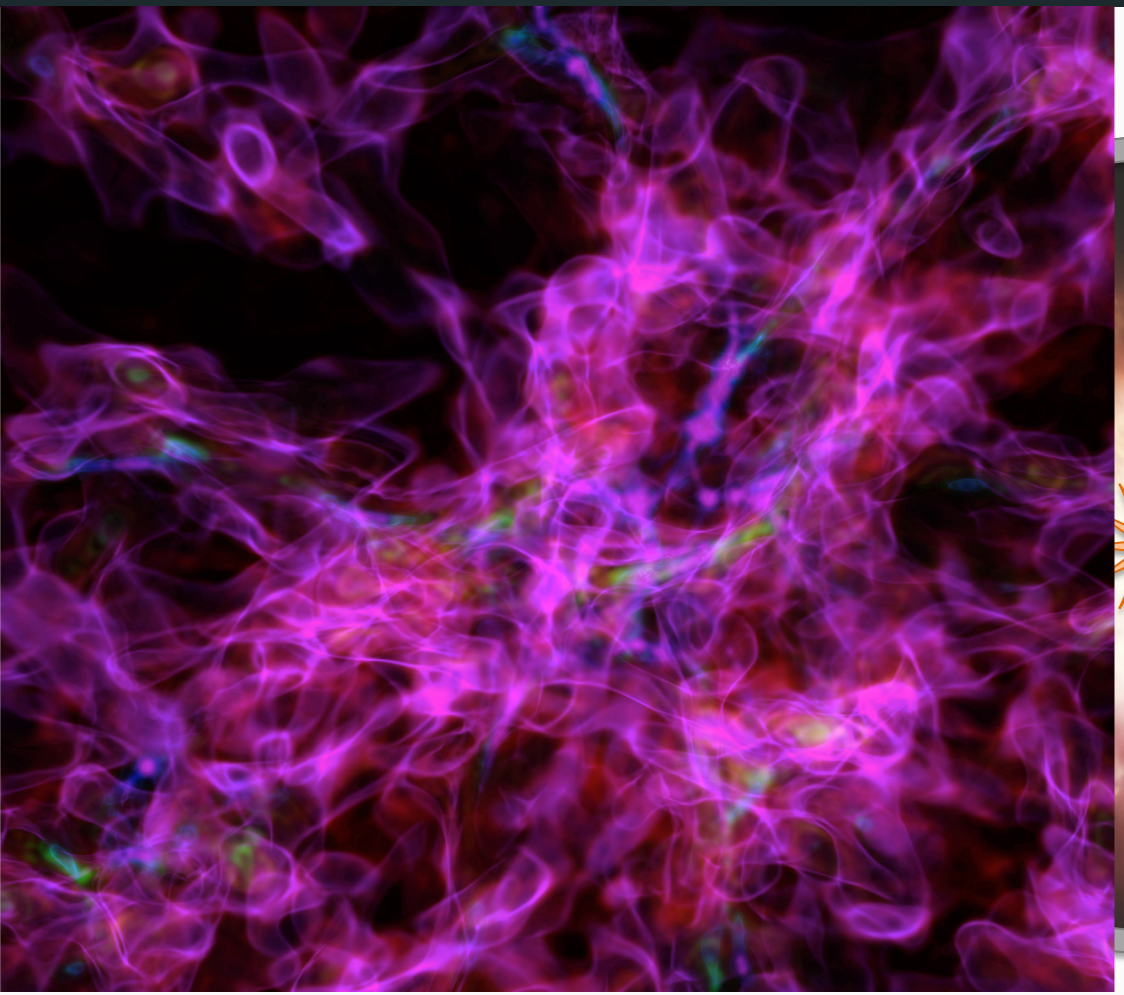
APPLYING RADIATION HYDRODYNAMICS TO RESONANCE LINES

- On the fly 3D Lyα radiation hydrodynamics is feasible with my new resonant discrete diffusion Monte Carlo method.
- Initial collapse of massive seed black holes, e.g. DCBHs.
- Study line driven winds, e.g. massive stellar systems and lanthanide-rich kilonova from binary neutron-star mergers.
- Scenarios where optically-thin approximations break down.

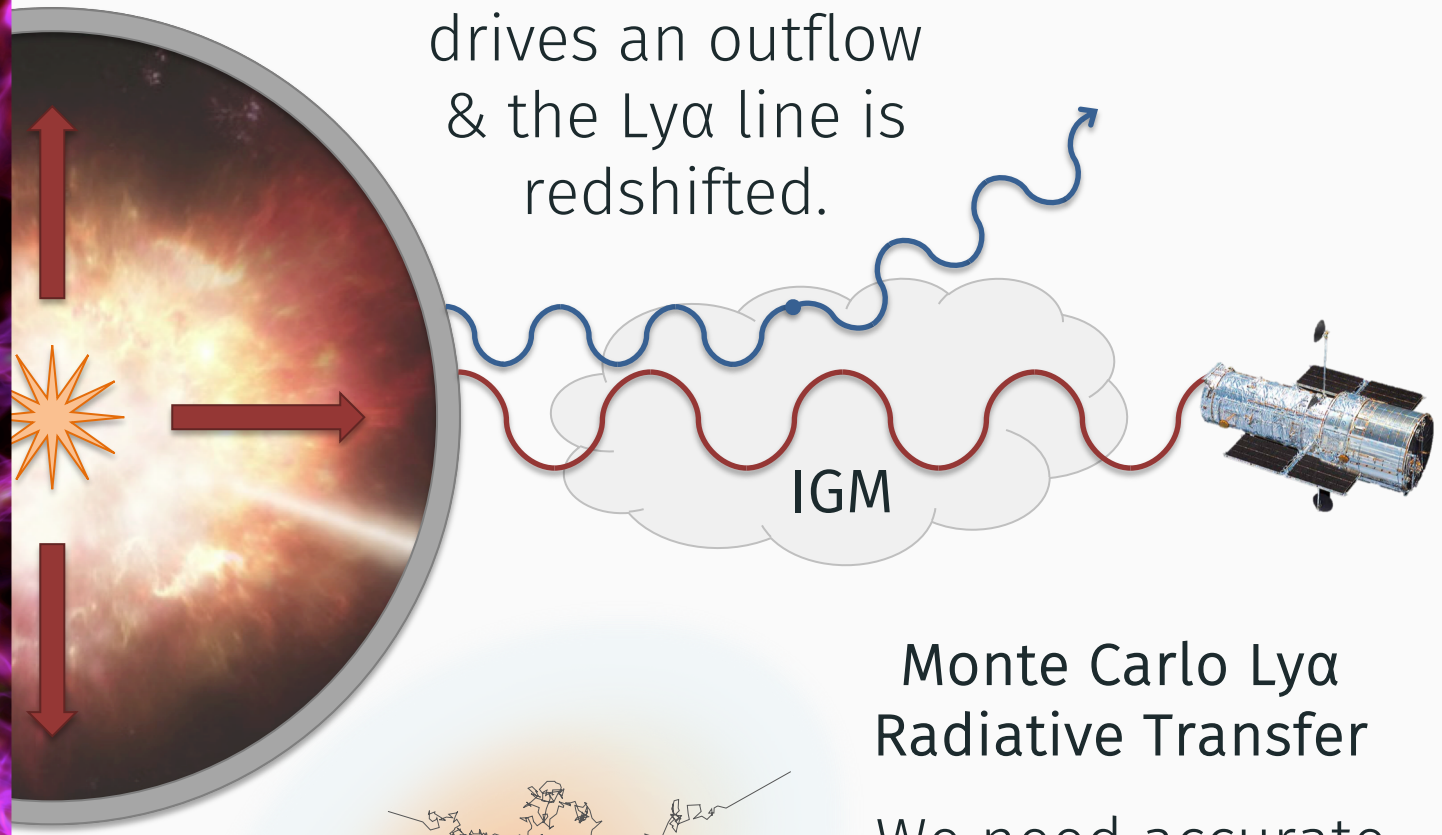


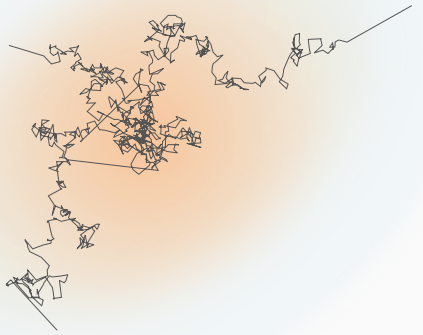


LEVERAGING Lyα AND OTHER PROBES FOR NEW PERSPECTIVES



Lyα can be used to study fundamental physics, source properties, large-scale environments, and even dynamics.



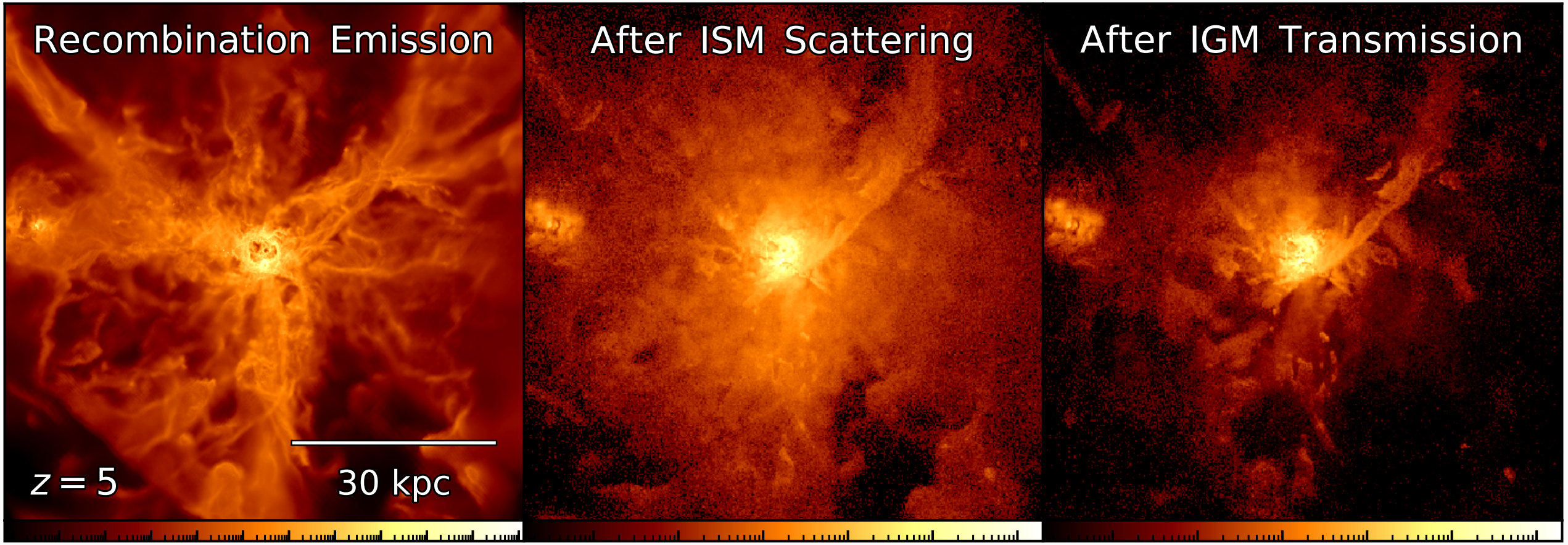


Monte Carlo Lyα Radiative Transfer

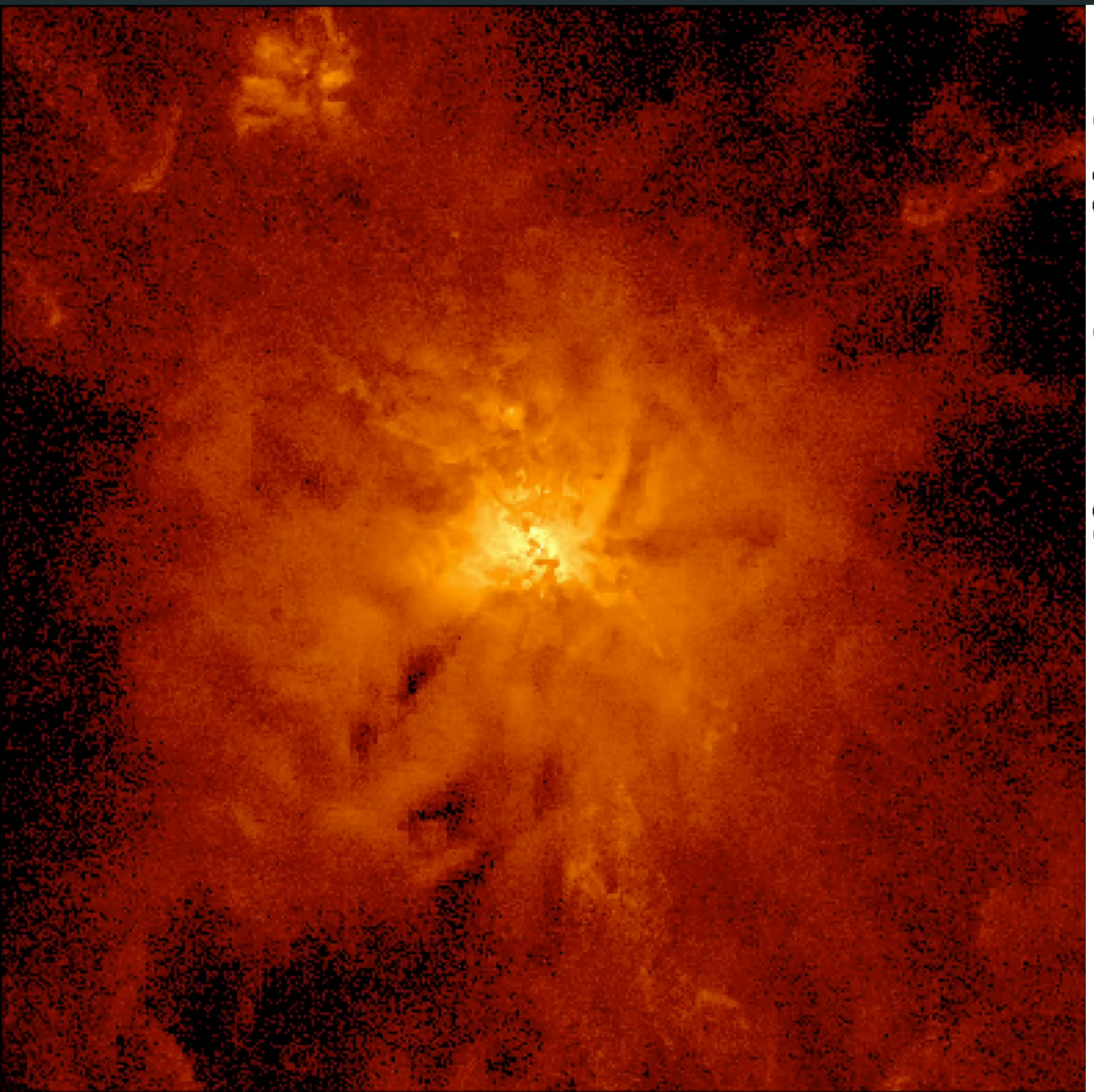
We need accurate Lyα RT simulations that resolve both the ISM and IGM.

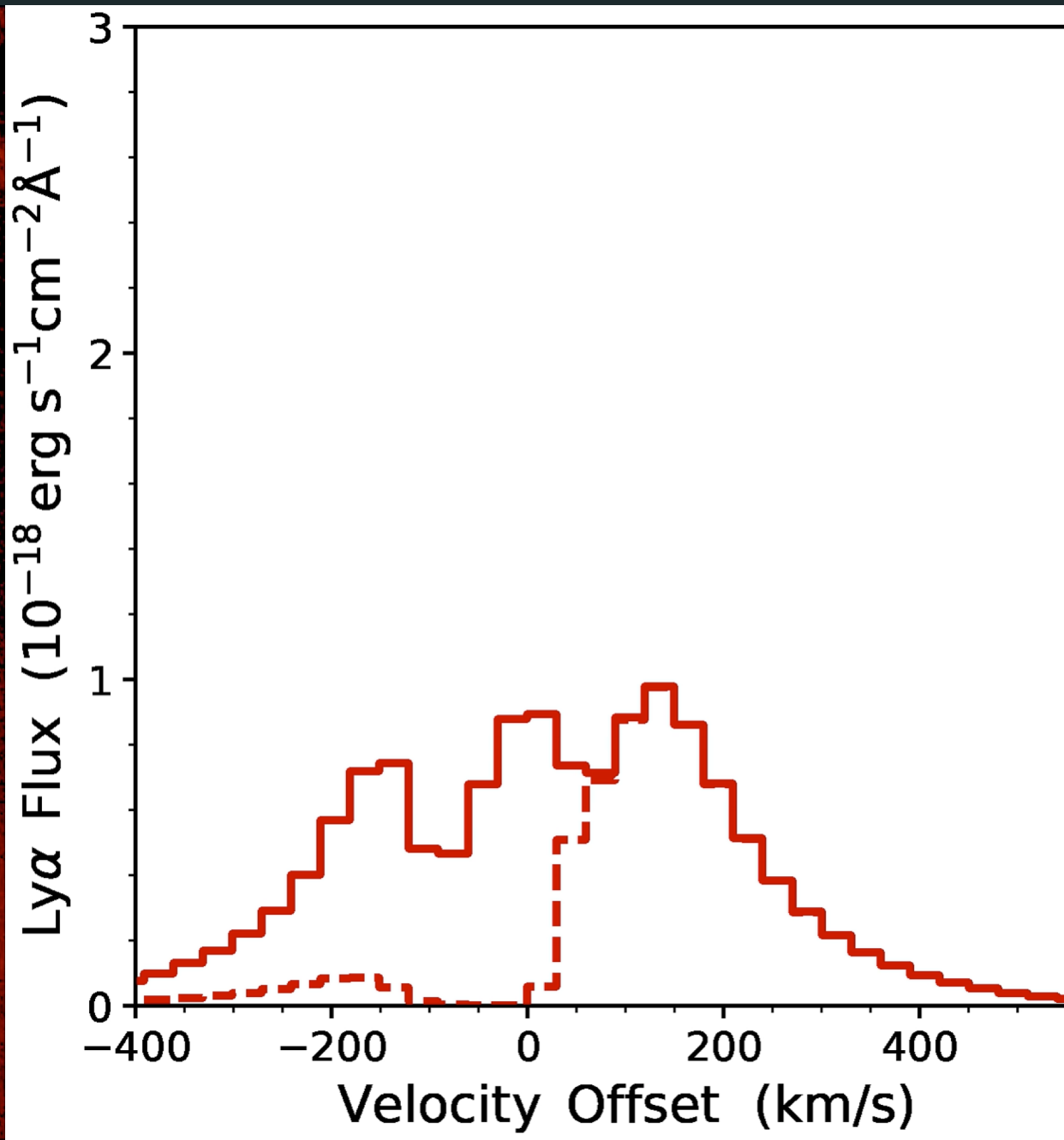
COSMOLOGICAL "ZOOM-IN" SIMULATION OF A REDSHIFT 5 GALAXY (GIZMO/FIRE, Ma et al. 2017)

Accurately model the ionizing radiation to obtain the recombination emission.
Follow the resonant scattering in the ISM and transmission through the IGM.

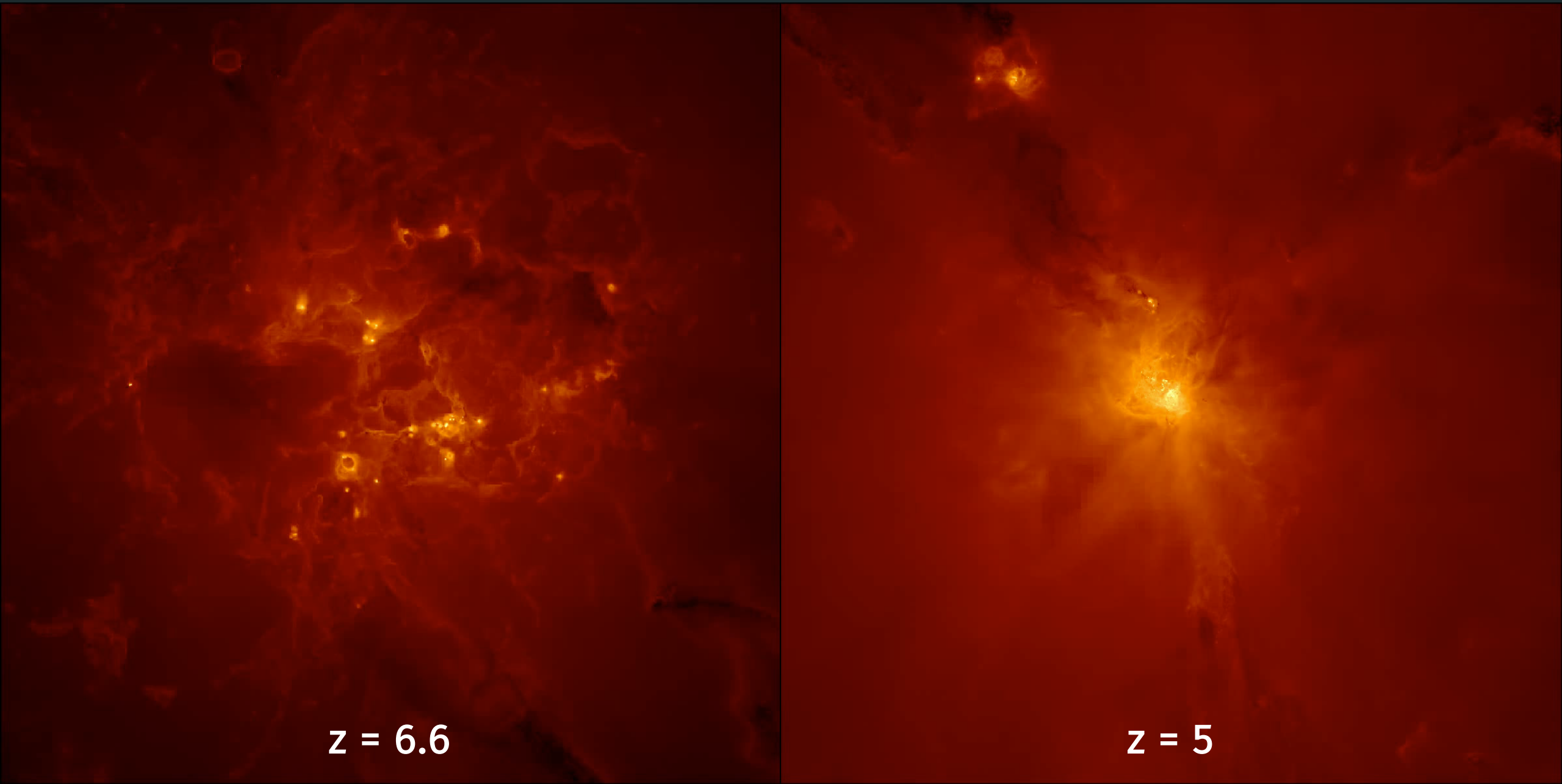


ROTATING CAMERA REVEALS NONTRIVIAL SIGHTLINE DEPENDENCE (CLOUDS, DOPPLER SHIFTS)

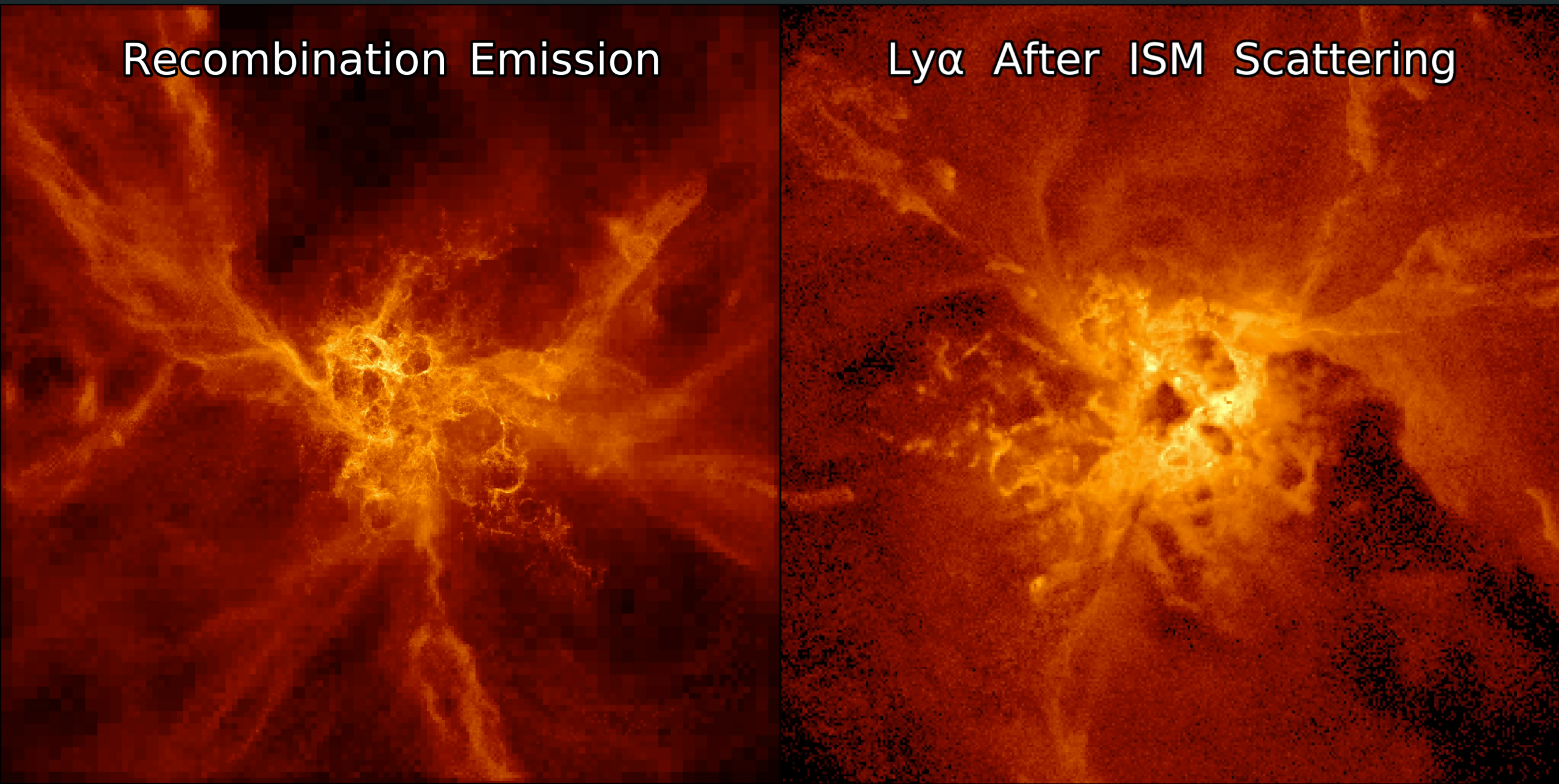




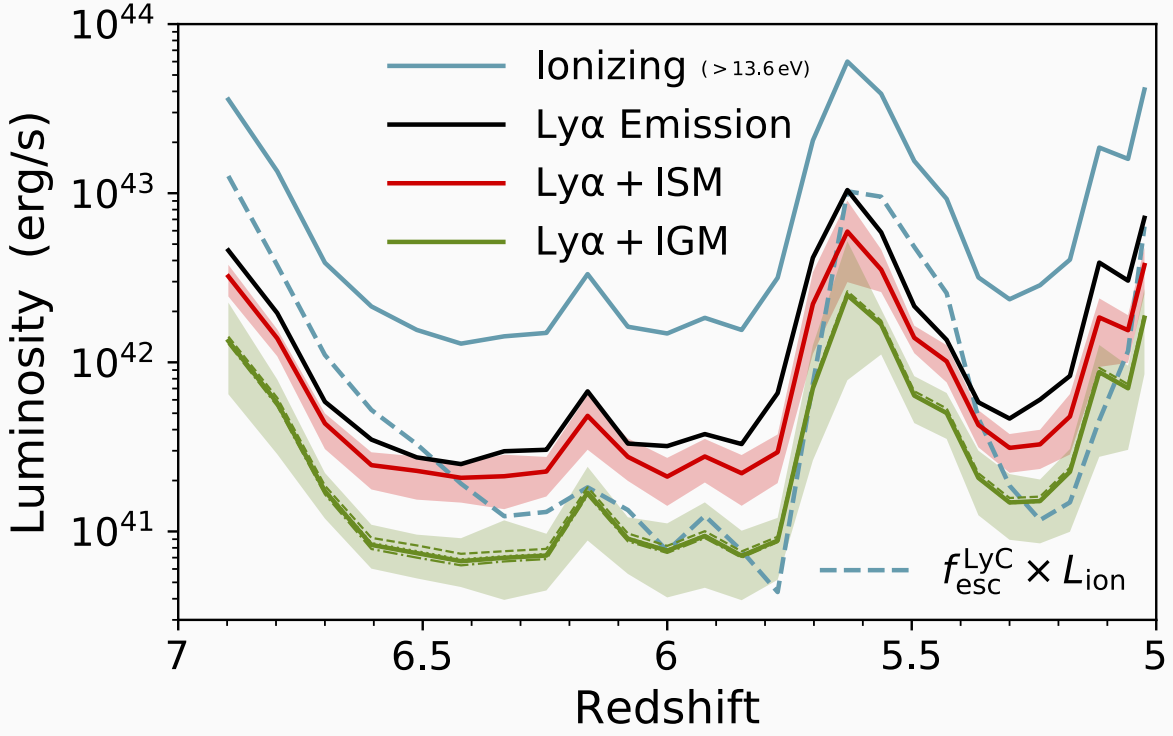
MORPHOLOGICAL DIFFERENCES IN THE LYMAN-ALPHA ENERGY DENSITY



TIME-DEPENDENCE OF LYMAN-ALPHA PROPERTIES



PROPERTIES OF THE EMERGENT Lyα LINE



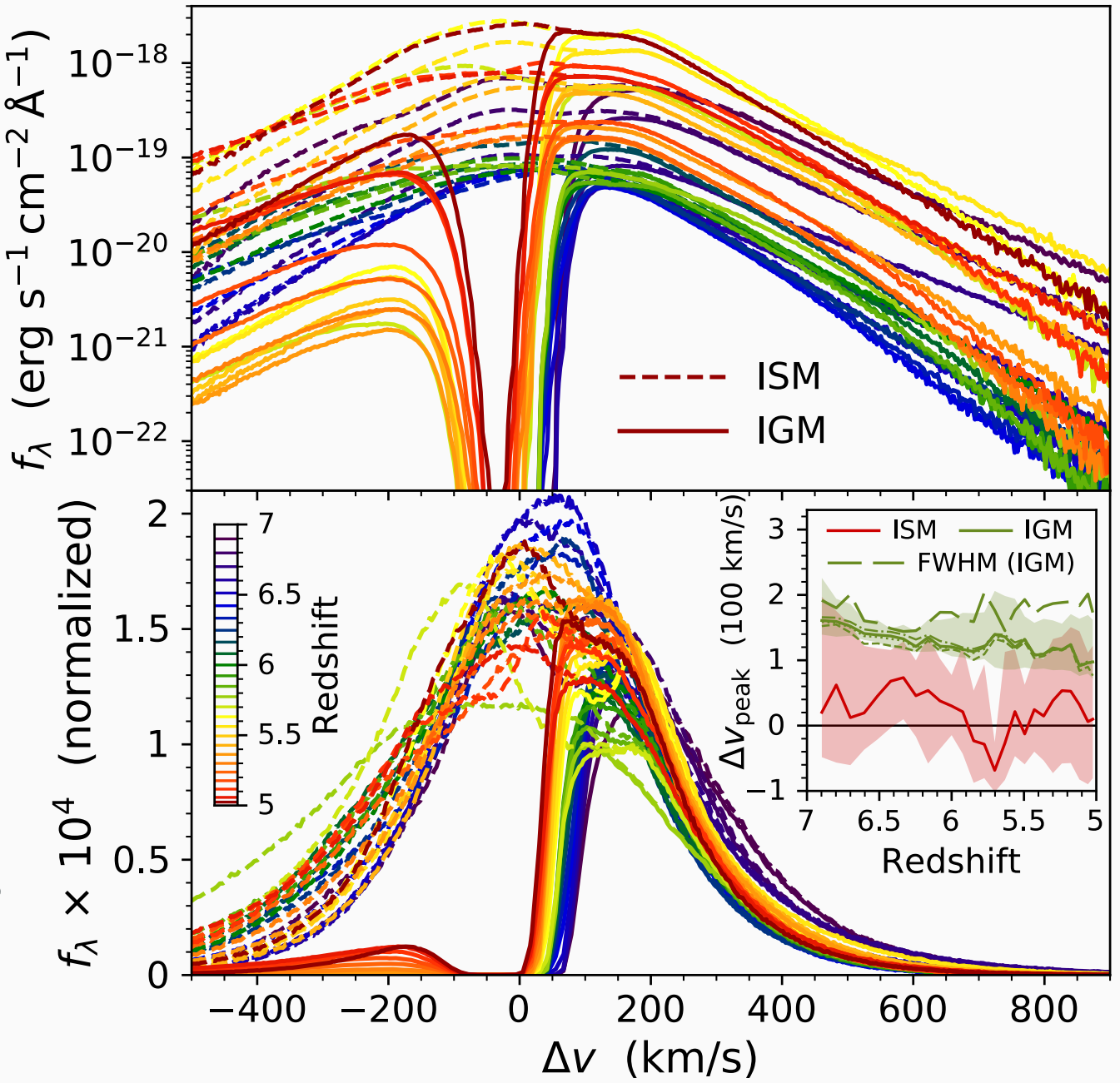
The Lyα line properties fluctuate in response to the star formation rate.

Time- and sightline-weighted medians:

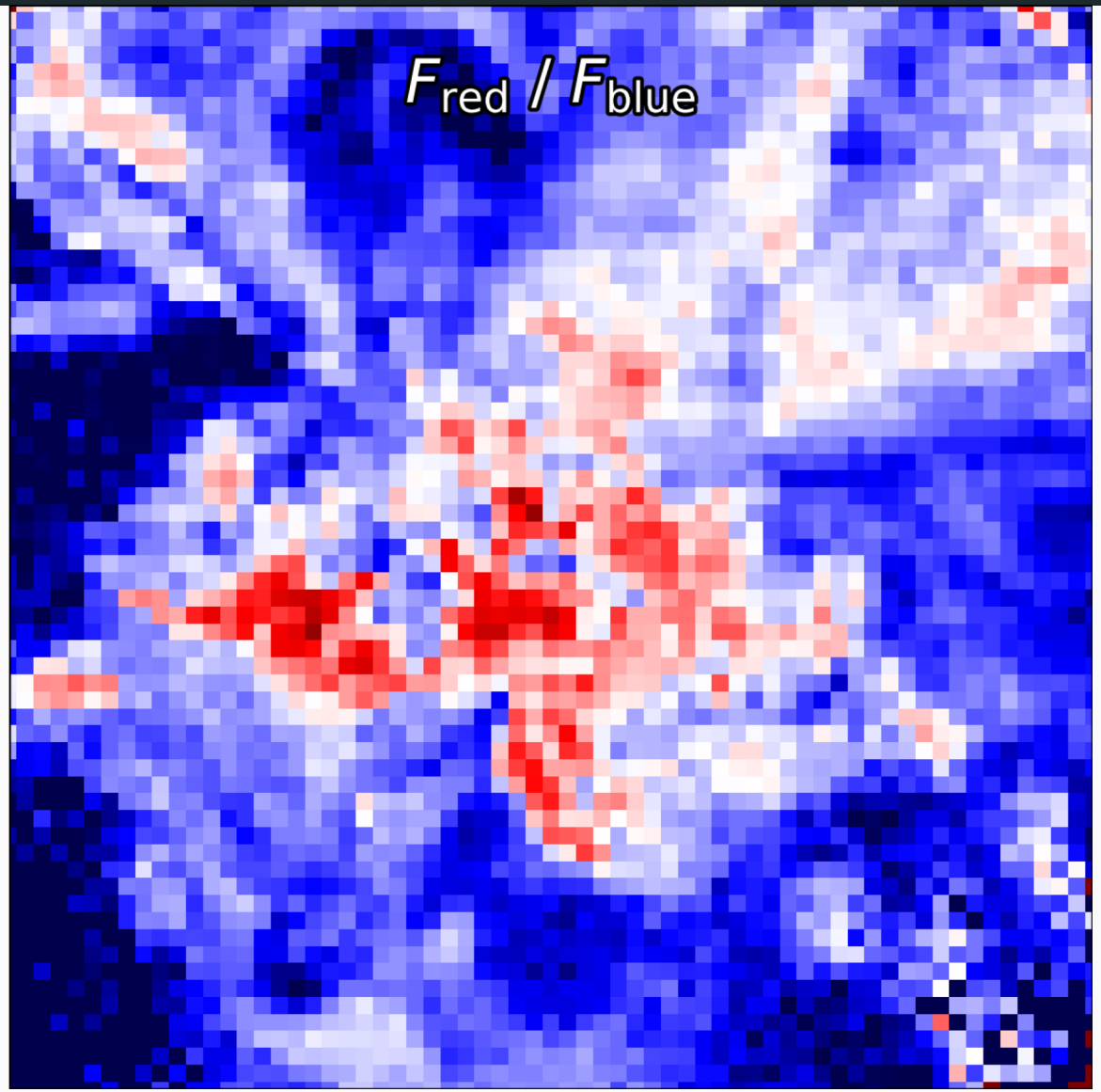
M_{vir} = 5x10^8 $M_\odot$, $f_{esc,Ly\alpha}$ = 66%, T_{IGM} = 40%

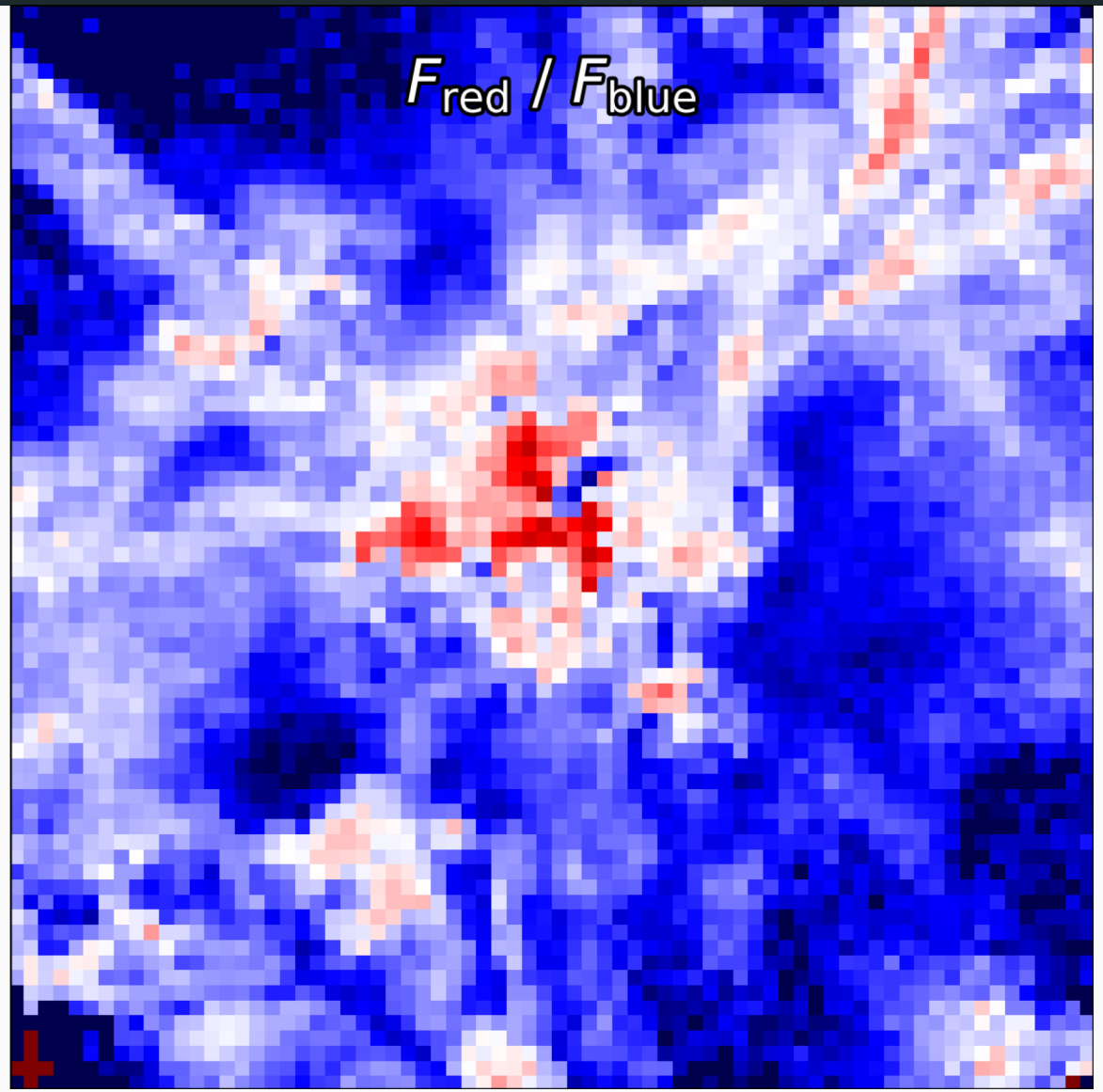
Δv_{peak} = 130 km/s, FWHM = 172 km/s

F_{LOS}/F_{iso} = 1 +/- 0.43, $EW_{Ly\alpha}$ = 23 Ang



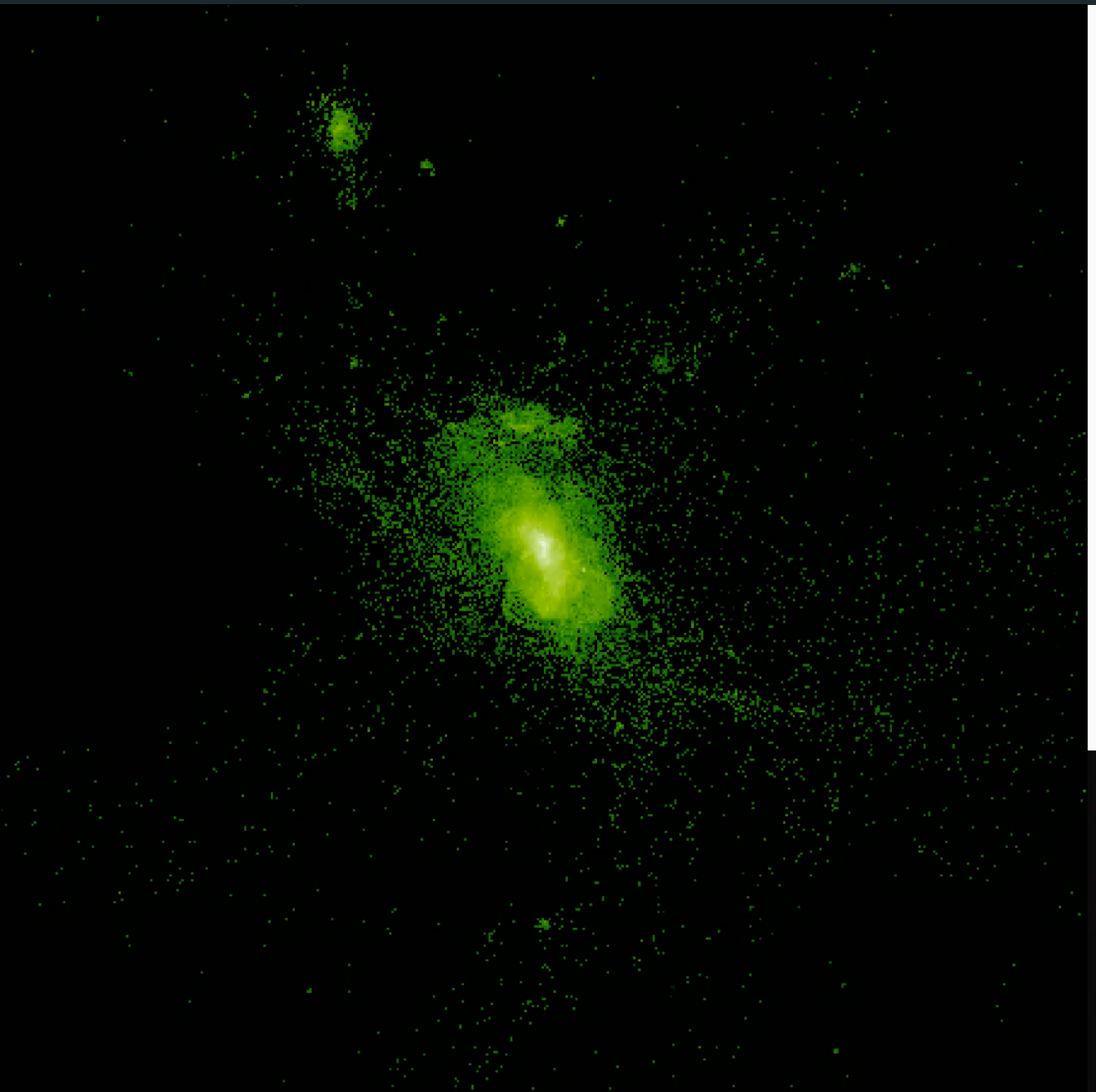
QUICK NOTE ABOUT KINEMATICS





Even with strong feedback, the Lyα haloes are “blue” while the core is ”red”.

SUMMARY



- Lyα sources provide clues about galaxy formation and evolution, CGM/IGM, large-scale structure, and the epoch of reionization.
- JWST/GMT/TMT/E-ELT will extend our view into the high-z frontier.
- On the fly 3D Lyα RHD is feasible with my new rDDMC method.