Galaxy Formation in Quasar Fields during Reionization

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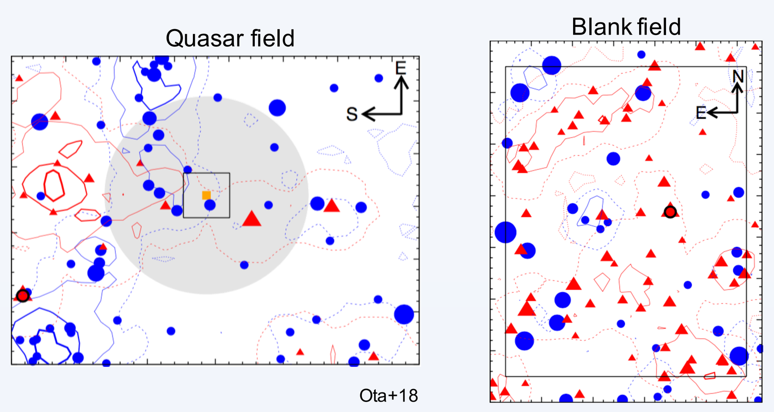
INTRODUCTION

Bright quasars are thought to reside in the most massive halos at high redshifts. These halos would exist in the most dense environments, meaning that we would expect to find an overensity of galaxies around these quasars. However, recent observations found that many z~6 quasar fields lack galaxies. This contradiction may potentially be explained by quasar radiative feedback. Previously this effect has been studied using idealized 1D spherical models. However, in reality galaxies are not spheres but have various shapes, and they reside in complex cosmological environments. Therefore, to robustly evaluate how efficient quasar radiative feedback is, we need to utilize cosmological simulations.



Observed galaxy distribution of a quasar field (left) and a blank field (right). The yellow square in the center of the left panel is a quasar at z=6.6. The red triangles are Lyman alpha emitters, which are usually interpreted as young galaxies, and the blue circles are Lyman break galaxies. The quasar field has significantly less Lyman alpha emitters.

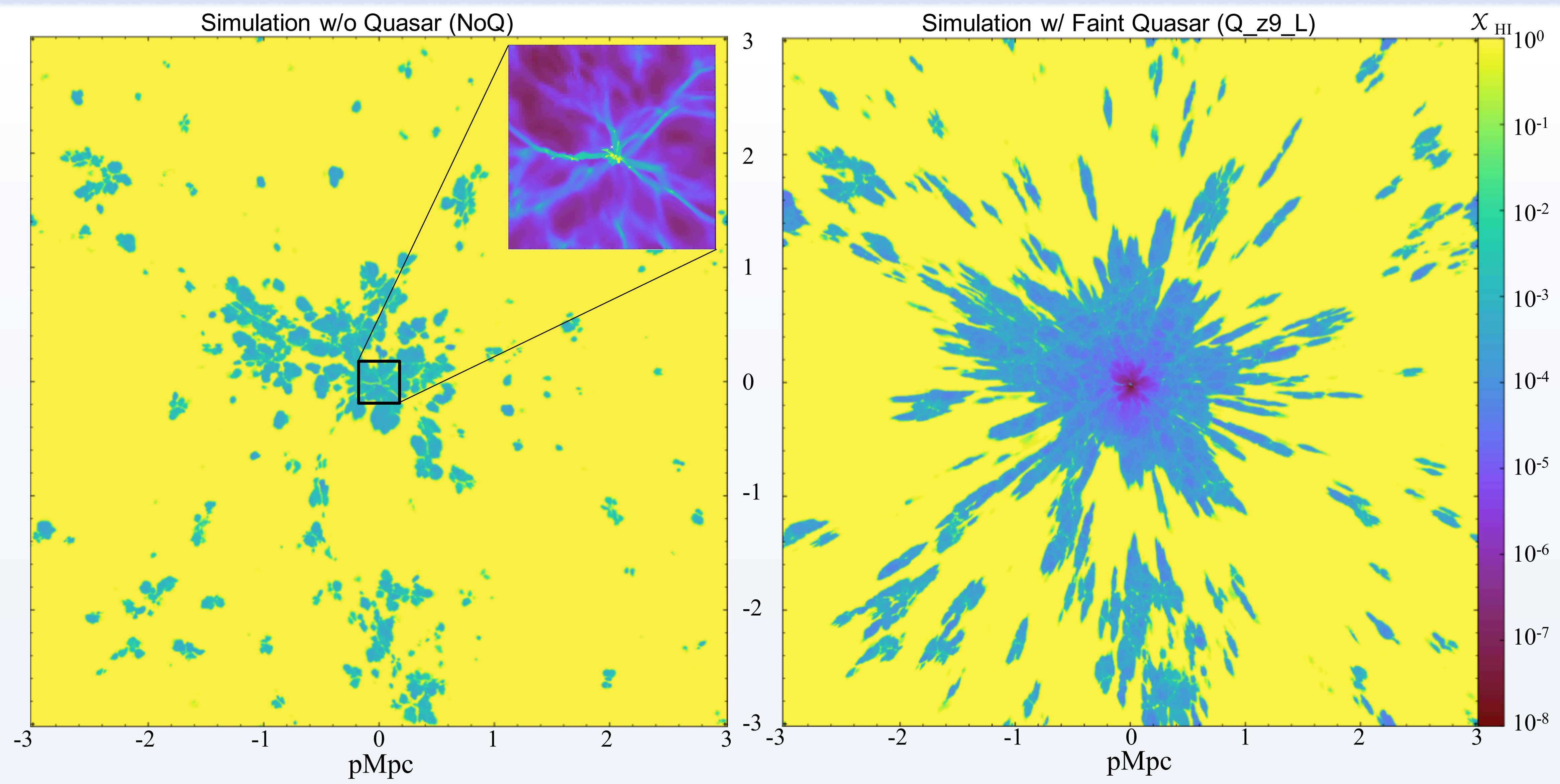
Here I present a suite of 3D radiative transfer cosmological simulations of quasar fields. I find that quasars suppress star formation in low mass galaxies. This suppression is mainly due to photo-dissociation of molecular hydrogen. Photo-heating also plays a role, but only after > 100 Myr. Quasar radiative feedback suppresses the faint end of the galaxy luminosity function, but the bright end is not impacted. This suggests that by counting the number of bright galaxies around quasars, we can put reliable constrains on the mass overdensity of quasar fields.

SIMULTATION SUITES

- Adaptive Refinement Tree Code:
  - 60 cMpc box size, 100 pc peak resolution
  - Radiative transfer fully coupled with gas dynamics
- Quasar Implementation:
  - Centered on the most massive halo at z=9
  - Light curve described by a light-bulb model
- Simulation Suite:

Sim Name	L_q [erg/s]	Turn-on Epoch
NoQ	-	-
Q_z9_L	1×10^{46}	z=8.9 - z=6.4
Q_z9_H	1×10^{47}	z=8.9 - z=6.4
Q_z7_H	1×10^{47}	z=6.8 - z=6.4
Q_z9_L_z8off	1×10^{46}	z=8.9 - z=8.2
Q_z9_L_z7off	1×10^{46}	z=8.9 - z=6.8

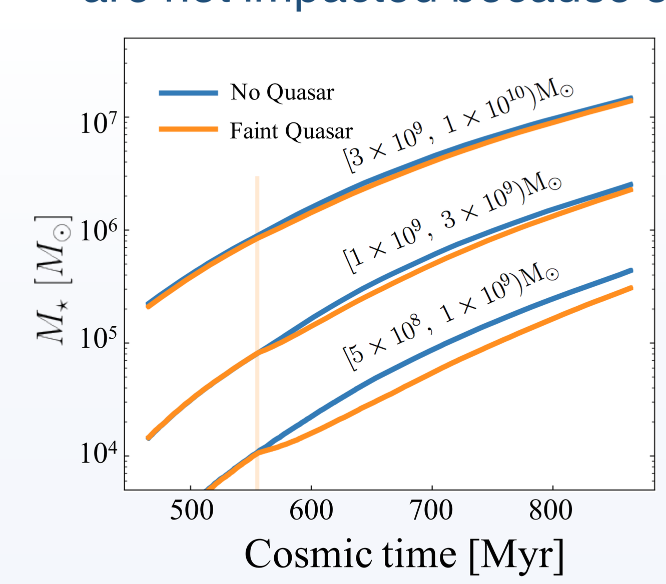
SIMULATION OUTPUTS



Neutral fraction map centered on the quasar. Left: Simulation without quasar radiation (NoQ). Right: Simulation with quasar radiation (Q_z9_L). At this moment the quasar has been on for 30 Myr. The zoom-in panel in the left figure is the density map, showing the quasar host experiencing mergers.

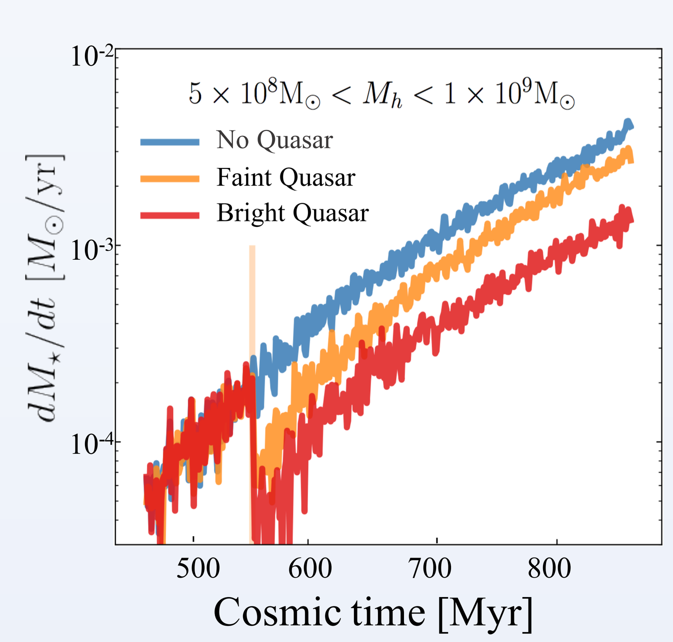
RESULTS: Star Formation and Gas Properties

❖ Quasar radiative feedback suppresses star formation in low mass halos. High mass halos are not impacted because of shielding.



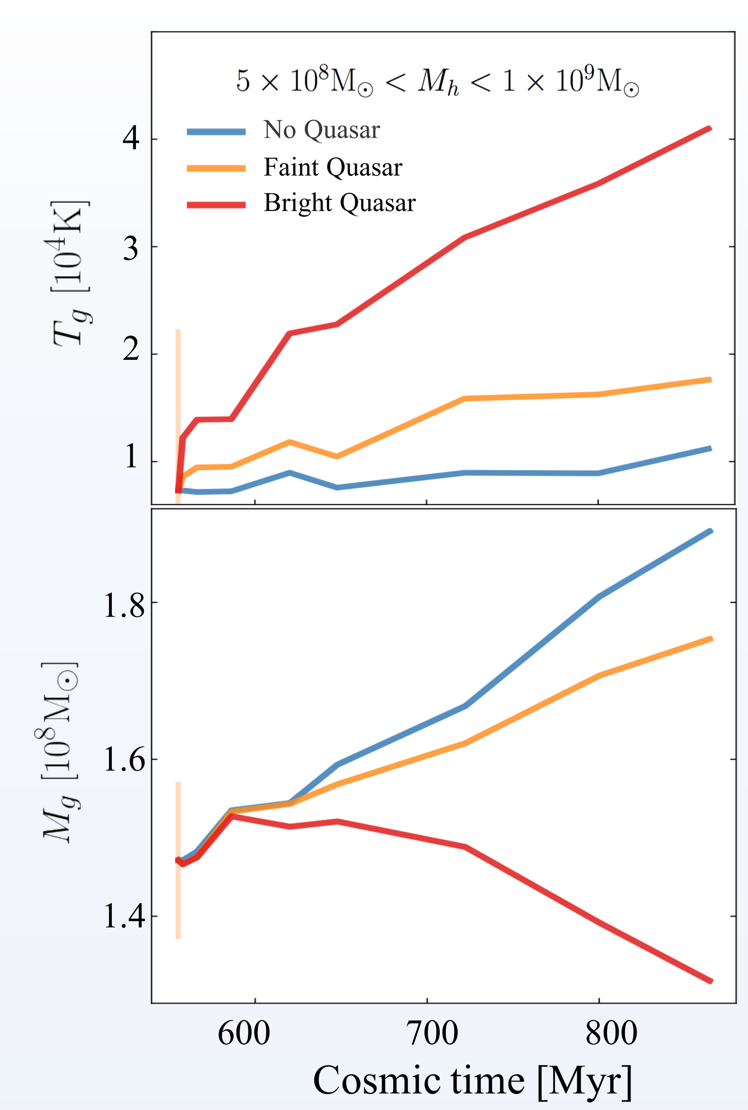
Star formation histories averaged over halos with different masses within 1 pMpc from the quasar host halo. The quasar turns on at z=9, marked by the vertical line.

❖ Suppression happens on short timescales, because photo-dissociation happens instantly.



Averaged star formation rates of low mass halos in no quasar run NoQ (blue), faint quasar run Q_z9_L (orange) and bright quasar run Q_z9_ H (red).

❖ Quasar radiation heats surrounding halos quickly, but gas gets removed on much longer timescales (~100Myr).

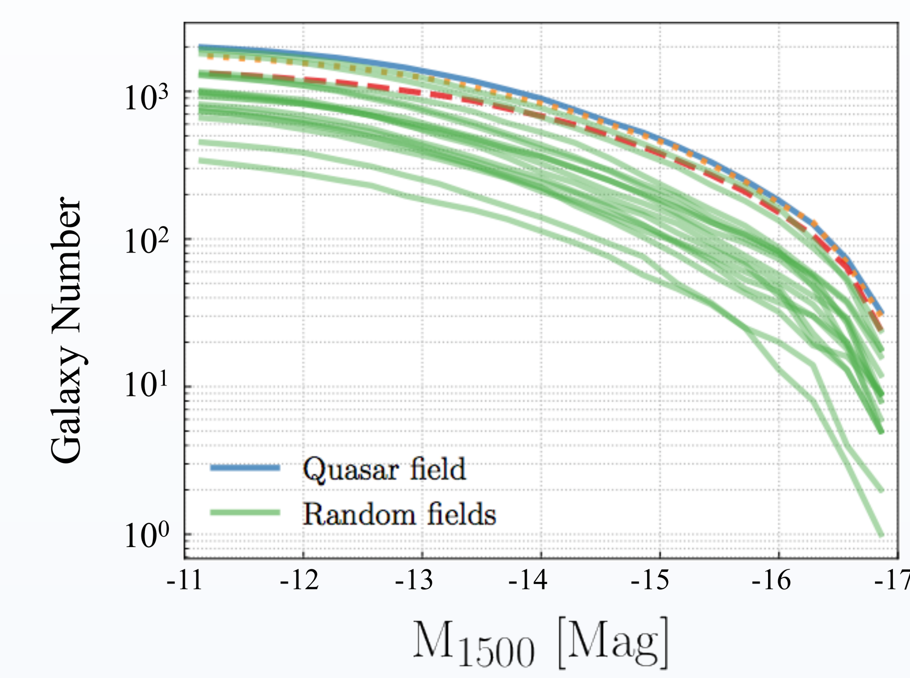


Gas temperature (upper panel) and gas mass (lower panel) evolution of low mass halos. The vertical line marks the time when the quasar turns on. Gas temperature increases instantly when the ionizing front sweeps through the halos, but gas mass in the halo takes roughly a sound crossing time to change.

RESULTS: Luminosity Functions

❖ Quasar radiative feedback suppresses the faint end of the luminosity function, but only by a small amount.

❖ The degree of suppression on star formation is much smaller than the field-to-field variation.



Cumulative luminosity functions within a sphere of 1 pMpc centered on different fields. The blue line is from the no quasar run centered on the quasar. The orange line and the red line show how this cumulative luminosity function changes under faint and bright quasar radiation for 309 Myr. The green lines are from the no quasar run centered on random positions of the simulation box.

TAKE AWAY MESSAGES

❖ **Quasar radiation suppresses star formation in surrounding low-mass galaxies.**

❖ **But the field-to-field variation is much larger than the difference made by the quasar radiative feedback.**

REFERENCES

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