HOW REIONIZATION QUENCHES DWARF GALAXIES

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Katz et al. 2019 - arXiv 1905.11414
MISSING SATELLITES PROBLEM

Dark Matter Only Simulation

Observations
Supernova Feedback: Dekel & Silk 1986

- SN Feedback effective at $v < v_{\text{crit}}$

Reionization Feedback: Bullock+ 2000

- Reionization Feedback effective at $v < 30 \text{ km/s}$

$z_{\text{re}} = 8, f = 0.3$
THE PHYSICS OF RADIATION FEEDBACK

Prolonged cooling times

Photoevaporation

Reduced Accretion

Efstathiou 1992

Shapiro+ 2004

Noh+ 2014
INTRODUCING THE SPHINX SIMULATIONS

Suite of cosmological radiation hydrodynamics simulations run on PRACE

• Includes 5, 10, and 20 Mpc boxes
• Resolution 10.9 pc
• Stellar Mass: $10^3 M_{\text{sun}}$
• DM Mass: $2.5e5 M_{\text{sun}}$ ($3.1e4 M_{\text{sun}}$ – hi-res)
• Variable speed of light approximation (up to 0.2c)
• Mechanical SN feedback
• 3 radiation bins (HI, HeI, and HeII ionizing)
• Single + Binary Star SEDs
• Post-Processed with RASCAS for Lya and Escape Fraction
REIONIZATION SMOOTH THE IGM

Without Reionization

Dark Matter

With Reionization
THE GAS CONTENT OF FILAMENTS IS STRONGLY IMPACTED BY REIONIZATION

Before reionization

After reionization

$\rho_b[g/cm^3]$ vs $R[kpc]$ for different redshifts ($z=6$, $z=7$, $z=8$, $z=9$)
EXTRA PRESSURE SUPPORT REMOVES GAS AND PREVENTS ACCRETION ONTO FILAMENTS

Central gas mass reduced by 80%-90%
Gas inflow rates at the virial radius are significantly reduced.

\[ \dot{M} \propto M^{1.15} \]

Graphs showing gas inflow rates vs. redshift for different scenarios of reionization.
BARYON FRACTIONS ARE REDUCED AS REIONIZATION PROGRESSES

Supernova feedback dominates

Radiation feedback dominates

Without Reionization
REIONIZATION IS INHOMOGENEOUS

 Regions around high mass galaxies reionize first

 Regions around low mass galaxies reionize late

\[
\begin{align*}
\text{Mean} & \quad \text{Median} & \quad \text{Mode} \\
10^7 & \quad 10^8 & \quad 10^9 & \quad 10^{10} \\
\text{Reionization Redshift} & \quad \text{M}_{\text{vir}} [\text{M}_\odot] \\
\end{align*}
\]
THE REDSHIFT BARYON FRACTION IS A DIRECT PROBE OF REIONIZATION
MOST STARS FORM AFTER REIONIZATION: DWARF GALAXIES ARE QUENCHED BY STARVATION

Stars formed before reionization

Stars formed after reionization
MOST STARS FORM AFTER REIONIZATION: DWARF GALAXIES ARE QUENCHED BY STARVATION
REIONIZATION SIMULATIONS OF OUR LOCAL GROUP

\[
\log_{10} \left( \frac{\Sigma}{M_\odot \text{kpc}^{-2}} \right)
\]
M31 MIGHT SUPPRESS DWARF GALAXY FORMATION IN THE MILKY WAY
CONCLUSIONS

• Reionization predominantly quenches dwarf galaxies by suppressing inflows
• Much of this is regulated by the amount of matter that can be accreted onto filaments
• Star formation can continue long after reionization
• The MW may have been reionized by M31
FILAMENTS ARE THE LAST REGIONS OF THE UNIVERSE TO REIONIZE
GAS OUTFLOWS ARE STRONGLY ENHANCED: PHOTOEVAPORATION
LOW MASS GALAXIES ARE ACTIVELY LOSING GAS
M31 COULD HAVE REIONIZED THE MILKY WAY.

**Diagram:**

- 
- Local Collisional MW M31 $z = 6$
- 
- $\chi_{\text{HII}, \text{mass}} \text{ or } \chi_{\text{HII}, \text{vol}}$
- 
- Vol Mass
- 
- $\bar{f}_{\text{esc}}$
- 
- Redshift
- 
- 6 8 10 12 14 16 18 20