Quenching Star Formation in Low-Mass Satellite Galaxies via Stripping

Sean P. Fillingham1, Michael C. Cooper1, Andrew B. Pace1, Michael Boylan-Kolchin2, James S. Bullock1, Shea Garrison-Kimmel3,4, Coral Wheeler1

1Department of Physics and Astronomy, University of California, Irvine, CA 2Department of Astronomy, The University of Texas at Austin, Austin, TX 3TAPIR, California Institute of Technology, Pasadena, CA 4Einstein Fellow

Motivation:
Recent studies of galaxies in the local Universe, including those in the Local Group, find that the efficiency of environmental quenching increases dramatically at low satellite stellar masses. This suggests a physical scale where the dominant quenching mechanism changes from a slow mode to a rapid mode. Through comparison to N-body simulations, the quenching timescale is relative to the host halo, can be inferred for a measured quenched fraction. The motivation is generally summarized as:

- High star mass satellite quenching timescales are consistent with starvation as the dominant quenching mechanism.
- Below 10^10 M☉ there is an abrupt change in the quenching timescale suggesting a change in the dominant quenching mechanism at low stellar masses.
- Gas removal via stripping is an attractive candidate since the restoring forces in these low-mass satellites should make them more susceptible to a “rapid mode” quenching mechanism such as ram pressure stripping.

Methods:
We implement an analytic form of instantaneous ram pressure stripping. The smallest radial distance from the center of each dwarf galaxy where the inequality is true defines the stripping radius. We integrate the Hi surface density profiles beyond this radius to determine the amount of Hi gas that was removed during the interaction.

\[ \rho_{\text{halo}} \frac{V^2}{r_{\text{sat}}} > \Sigma_{\text{gas}}(r) \frac{GM(r)}{r^2} \]

Adopted from literature
Average value from simulations

After instantaneous ram pressure stripping, we then allow up to 1 Gyr of turbulent viscous stripping. We first test whether the ISM-CGM interface is susceptible to Kelvin-Helmholtz instabilities. If so, we iteratively remove the ISM from each dwarf galaxy, rechecking the ISM-CGM conditions at each time step.

\[ M \approx 20 \left( \frac{R_{\text{ISM}}}{20 \text{kpc}} \right)^2 \left( \frac{n_{\text{halo}}}{10^{-3} \text{ cm}^{-3}} \right) \left( \frac{V_{\text{sat}}}{1000 \text{ km s}^{-1}} \right) \frac{M_{\odot}}{\text{yr}} \]

Conclusions:

1. High mass satellite quenching timescales are consistent with starvation as the dominant quenching mechanism.
2. Below a certain satellite stellar mass, the quenching timescales abruptly change, consistent with the critical stellar mass below which gas stripping becomes effective.
3. This critical mass is likely determined by the host properties, which ultimately set the average strength of the gas stripping, and should therefore shift to higher stellar masses for satellites interacting with more massive hosts.
4. The overall effectiveness of analytic gas stripping calculations is unable to fully quench the falling satellite population, suggesting that another mechanism could be ultimately quenching these galaxies or the analytic treatment of gas stripping is unable to fully capture the effectiveness. Feedback likely plays a role!