Quenching Star Formation in Low-Mass Satellite Galaxies via Stripping

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Motivation:

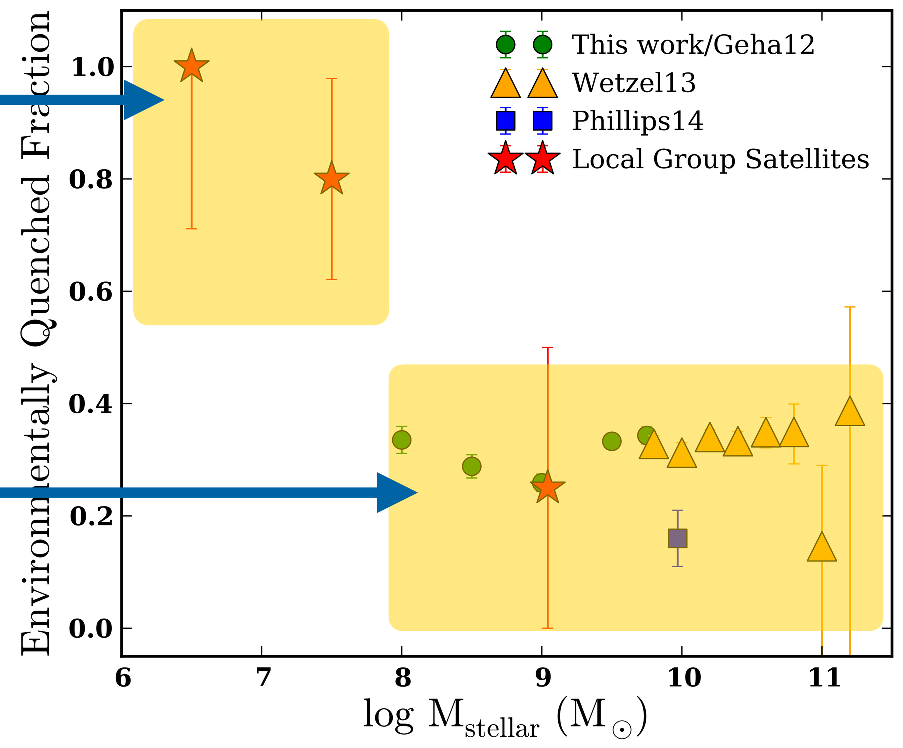
Recent studies of galaxies in the local Universe, including those in the Local Group, find that the efficiency of environmental quenching increases dramatically at low satellite stellar masses. This suggests a physical scale where the dominant quenching mechanism changes from a slow mode to a rapid mode.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

The motivation is generally summarized as:

- High stellar mass satellite quenching timescales are consistent with starvation as the dominant quenching mechanism.
- Below $10^8\,M_\odot$ 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.

Short quenching timescales, suggestive of ram pressure stripping.

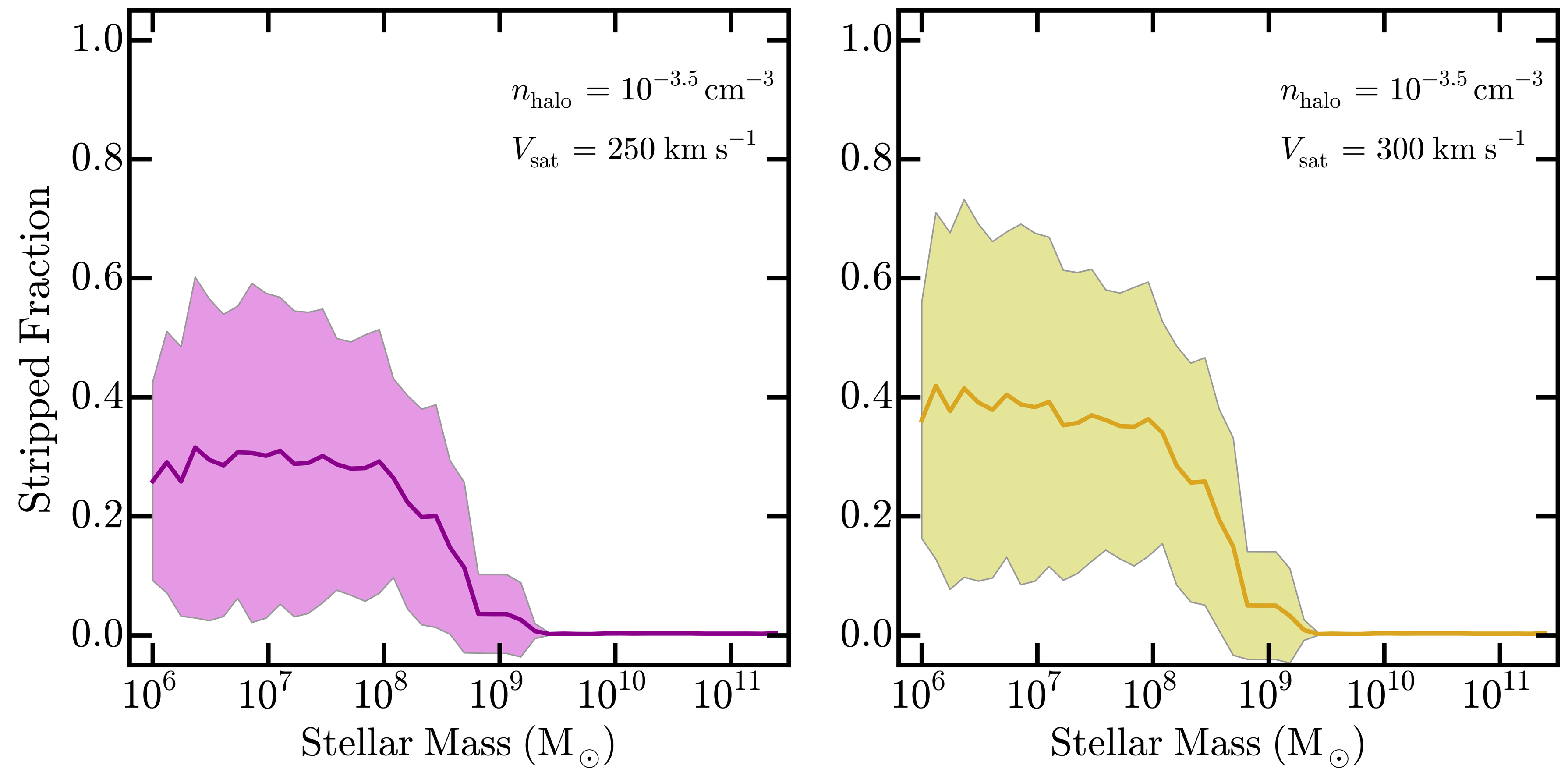
Long quenching timescales, consistent with starvation as the quenching mechanism.



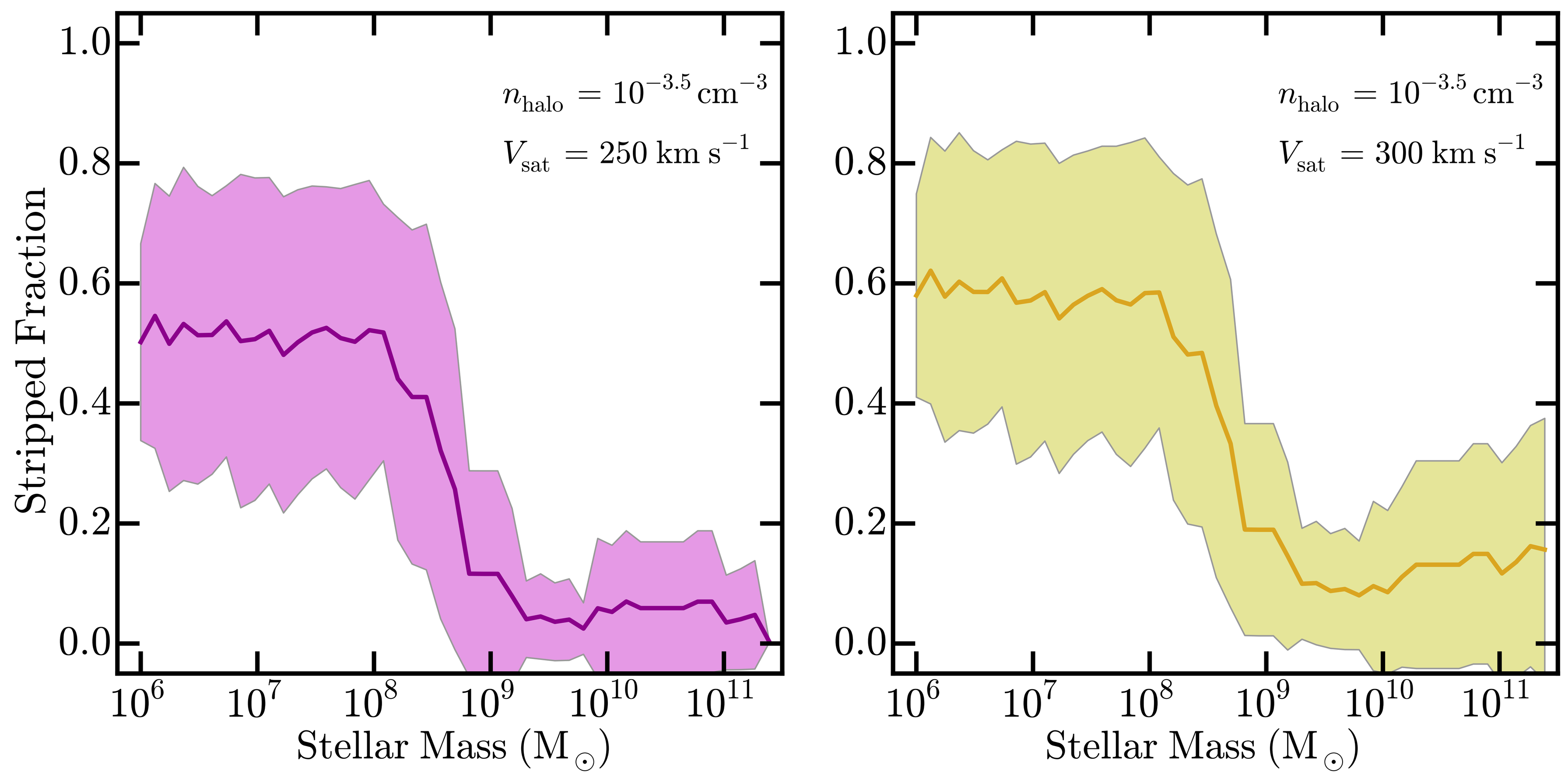
Results:

- Both ram pressure and turbulent viscous stripping "turn on" at roughly the correct satellite stellar mass scale, consistent with observations.
- While the amount of HI removed is quite sensitive to the properties of the host, the critical quenching mass is relatively robust.
- We find that gas stripping alone is insufficient and unable to reproduce the very high quenched fractions observed locally.
- A clumpy CGM would bring this work into agreement with observations such that every quenched satellite encountered a region of above average density and therefore more effective gas stripping.
- The scatter in the stripped fraction at fixed stellar mass is driven entirely by the variation in HI surface density profiles.

Ram Pressure Stripping Only



Ram Pressure plus Turbulent Viscous 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.

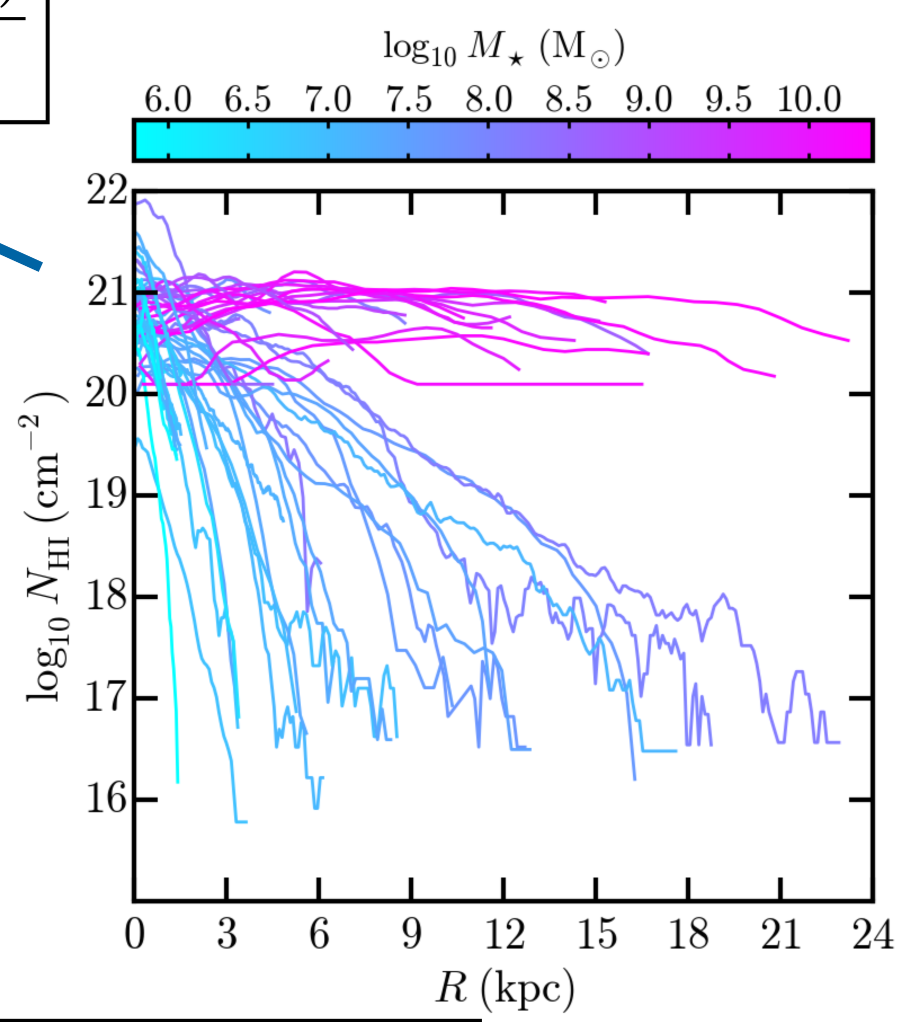
$$\rho_{\rm halo} V_{\rm sat}^2 > \Sigma_{\rm gas}(r)\,\frac{G\,M(r)}{r^2}$$

Adopted from literature

Average value from simulations

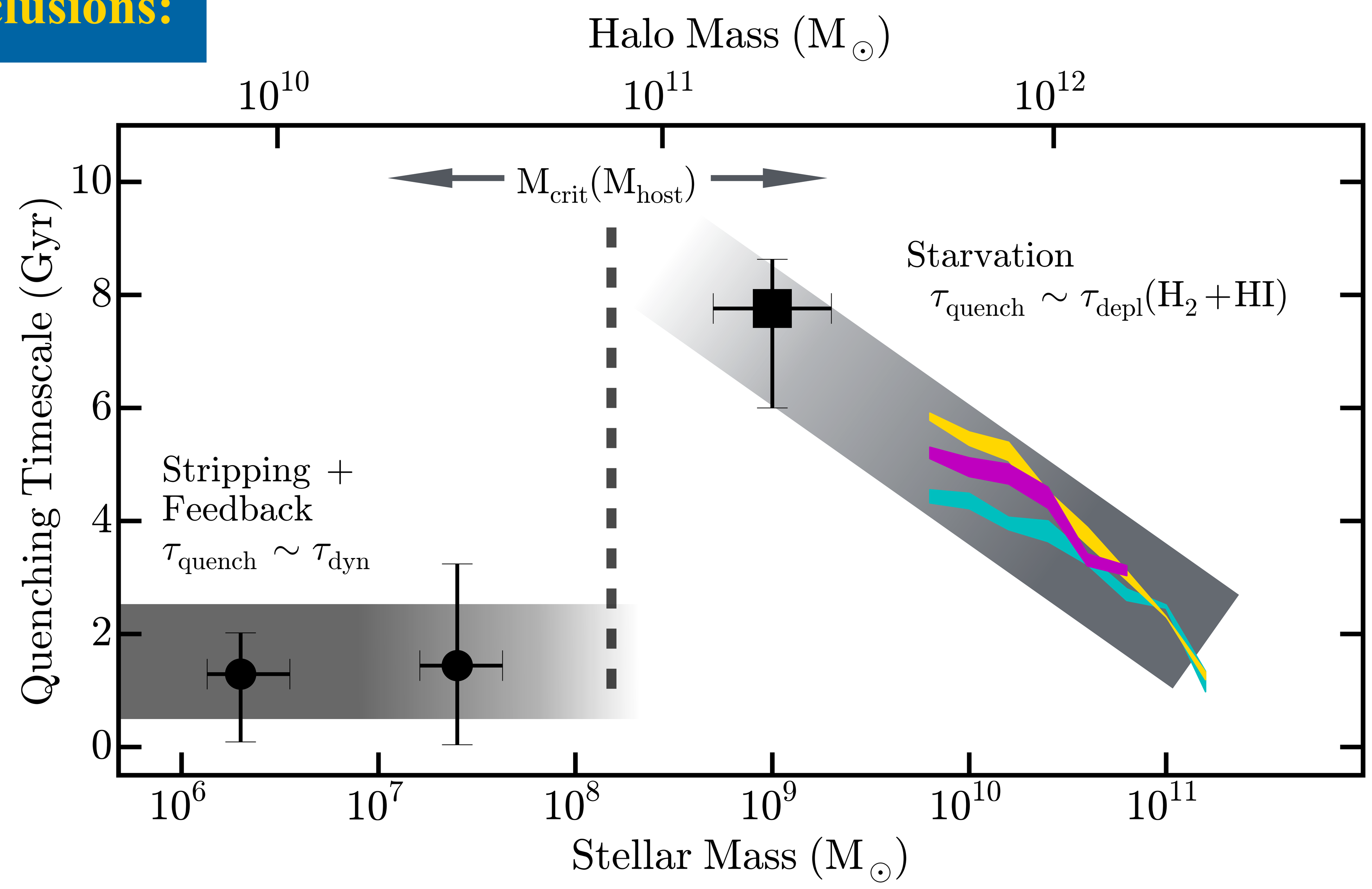
Abundance matching

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.



$$\dot{M} \approx 20\left(\frac{R_{\rm ISM}}{20\,{\rm kpc}}\right)^2\left(\frac{n_{\rm halo}}{10^{-3}\,{\rm cm}^{-3}}\right)\left(\frac{V_{\rm sat}}{1000\,{\rm km\,s^{-1}}}\right)\frac{{\rm M}_\odot}{\rm yr}$$

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 are unable to fully quench the infalling 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!

References:
Fillingham et al. 2015, MNRAS, 454, 2039; Fillingham et al. 2016, arXiv:1606.07810; Geha et al. 2012, ApJ, 757, 85; Phillips et al. 2015, MNRAS, 447, 698; Wetzel et al. 2015, ApJ, 808, L27; Wheeler et al. 2014, MNRAS, 442, 1396