Quenching Timescale of Central Galaxies

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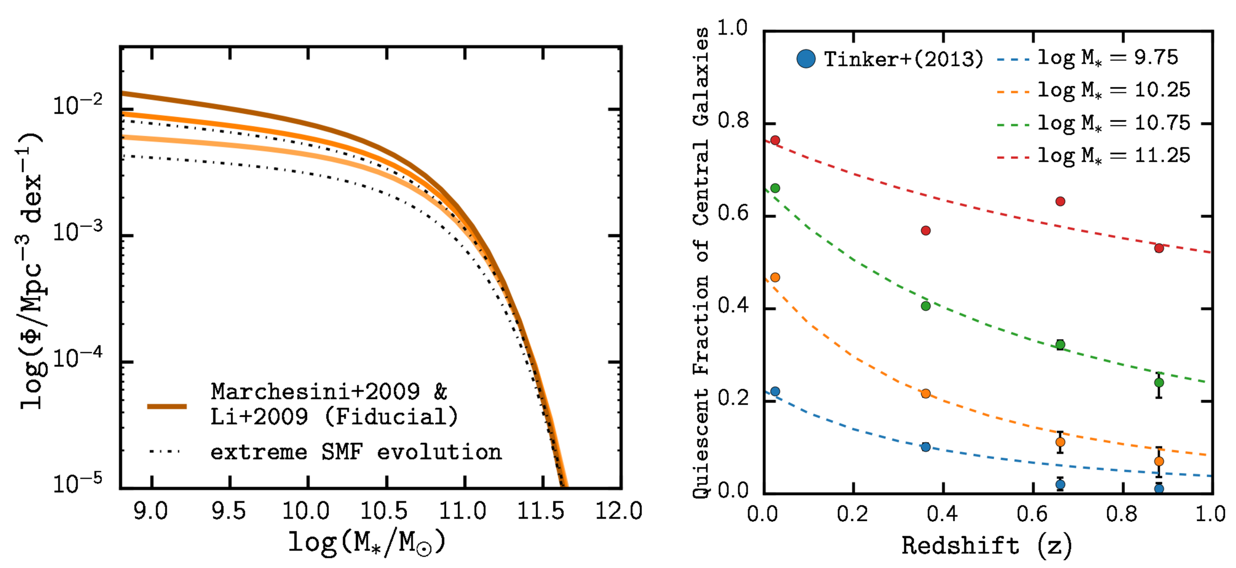
Galaxy Evolution at $z < 1$

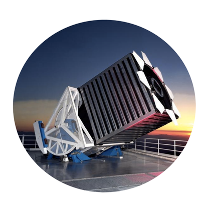
Observations of galaxies using large galaxy surveys have firmly established a global view of galaxy properties out to $z \sim 1$. We characterize the evolution of the galaxy population using the evolutionary trends of :

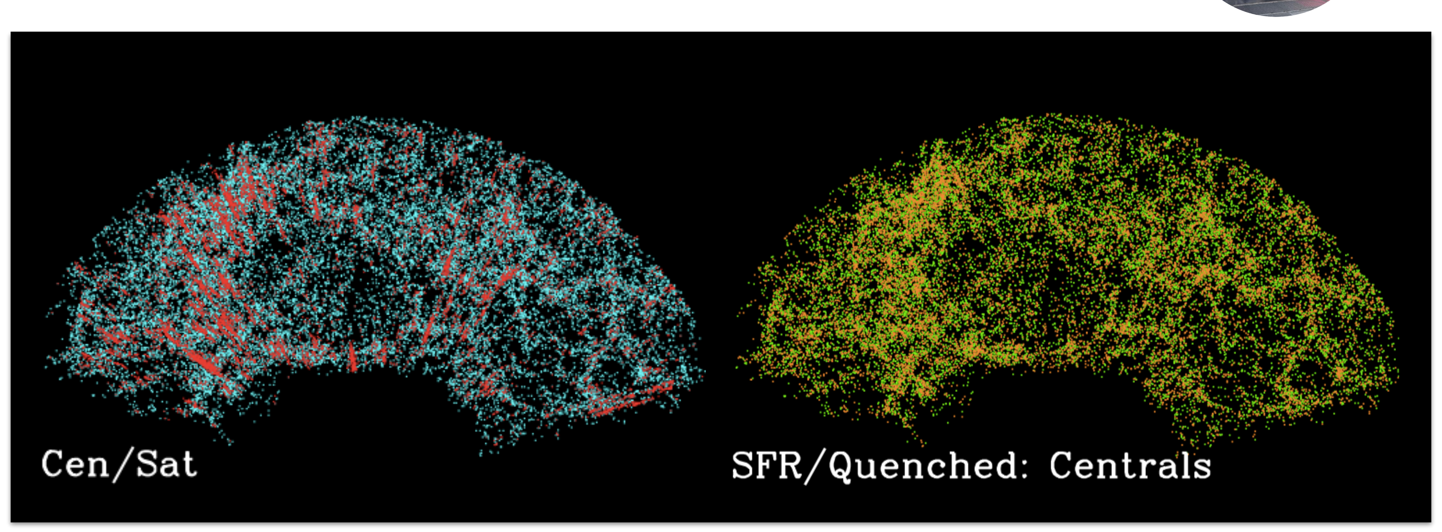
- star formation main sequence
- stellar mass function
- quiescent fraction



Left: SMF evolution parameterized using Li & White(2009) at $z = 0.05$ and interpolated with Marchesini+(2009) for $z > 0.05$. Right: Our parameterization of the central galaxy quiescent fraction fit to COSMOS measurements from Tinker+(2013).

Central Galaxies of SDSS DR7





A slice through a volume-limited SDSS DR7 galaxy sample. Left: Central (blue) and satellite (red) galaxies categorized using the Tinker+(2011) group finder. Right: Star-forming (green) and quiescent (orange) central galaxies of the sample.

Abstract

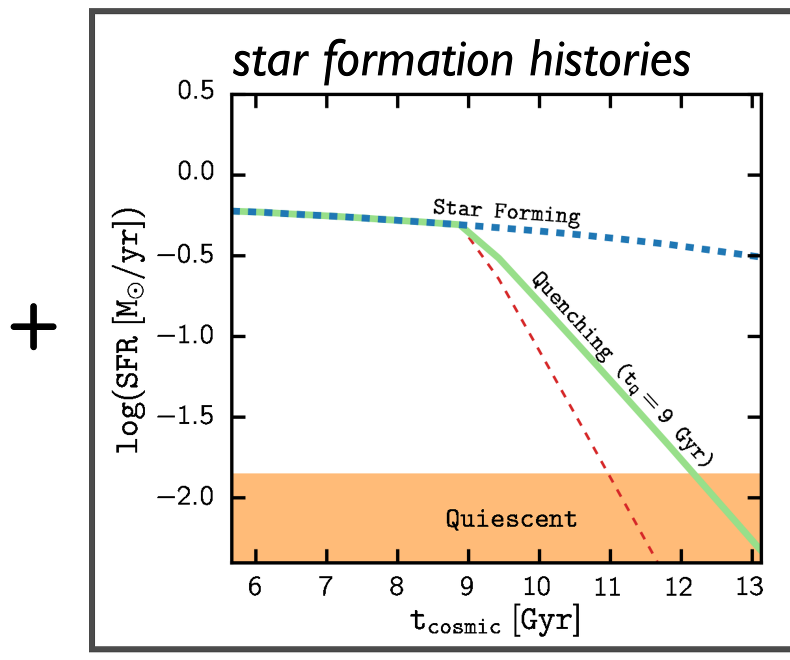
We combine a high resolution N-body simulation with observed evolutionary trends of the ``star formation main sequence'', quiescent fraction, and stellar mass function at $z < 1$ to construct a model that tracks the star formation histories and quenching of central galaxies. Using this model and comparing it to the central galaxies of the Sloan Digital Sky Survey Data Release 7 group catalog, we constrain the timescale of physical processes in central galaxies that are responsible for the cessation of star formation. As central galaxies make up over 70% of the galaxy population at $M > 10^{9.7} M_\odot$ and most galaxies on the red sequence evolved there as central galaxies, the mechanism(s) responsible for quenching central galaxies plays a crucial role in galaxy evolution as whole. While numerous mechanisms have been proposed, observations have not yet reached a consensus among them.

Our Model for Central Galaxies

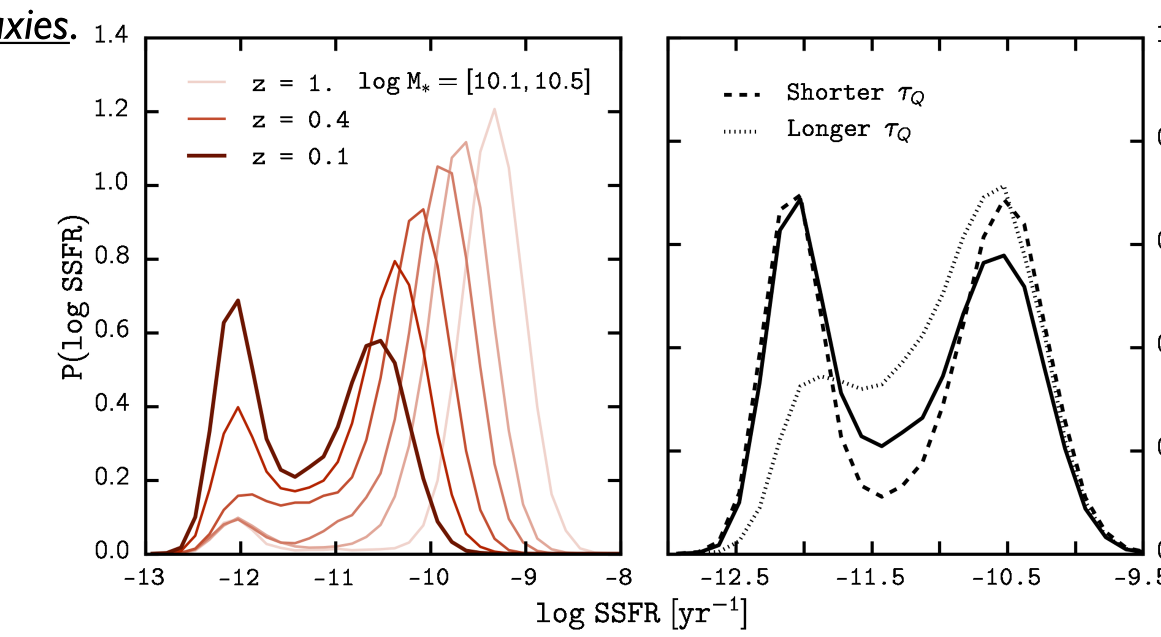
We use a high resolution N-body simulation in conjunction with observations of the SMF, SFMS, and quiescent fraction at $z < 1$, to construct a model that statistically tracks the star formation histories of central galaxies.

TreePM
N-body simulation
+
subhalo abundance matching

+



The parameters of our model dictate the height of the initial green valley at $z = 1$, the quenching probability, and most importantly the quenching timescale of central galaxies.



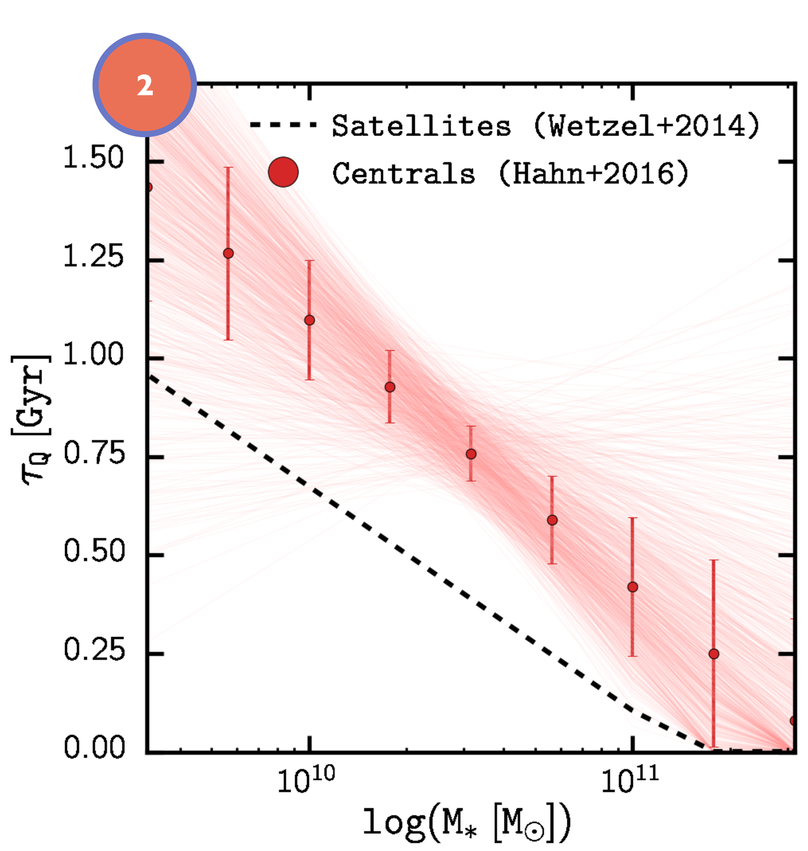
Left: The SSFR distribution of the central galaxies in our model, which evolves the star formation of central galaxies from $z \sim 1$ to 0.05. Right: For a longer quenching timescale, galaxies remain in the green valley longer and therefore the height of SSFR distribution green valley will be higher. For a shorter quenching timescale, the height of SSFR distribution green valley will be lower.

Results

1 Using Approximate Bayesian Computation (ABC) with our model, we infer parameter constraints that best reproduce the observations of the central galaxy SSFR distribution from the SDSS DR7 group catalog and the central galaxy quiescent fraction evolution.

2 The quenching timescale of central galaxies exhibit a significant mass dependence: more massive central galaxies have shorter quenching timescales. Over the stellar mass range $10^{9.5} - 10^{11.5} M_\odot$, τ_Q^{cen} spans $1.2 - 0.5$ Gyr. Central galaxies take roughly 2 to 5 Gyr to traverse the green valley. Also, the quenching timescale of central galaxies is significantly longer than the quenching timescale of satellite galaxies suggesting that different physical mechanisms are responsible in satellites versus centrals.

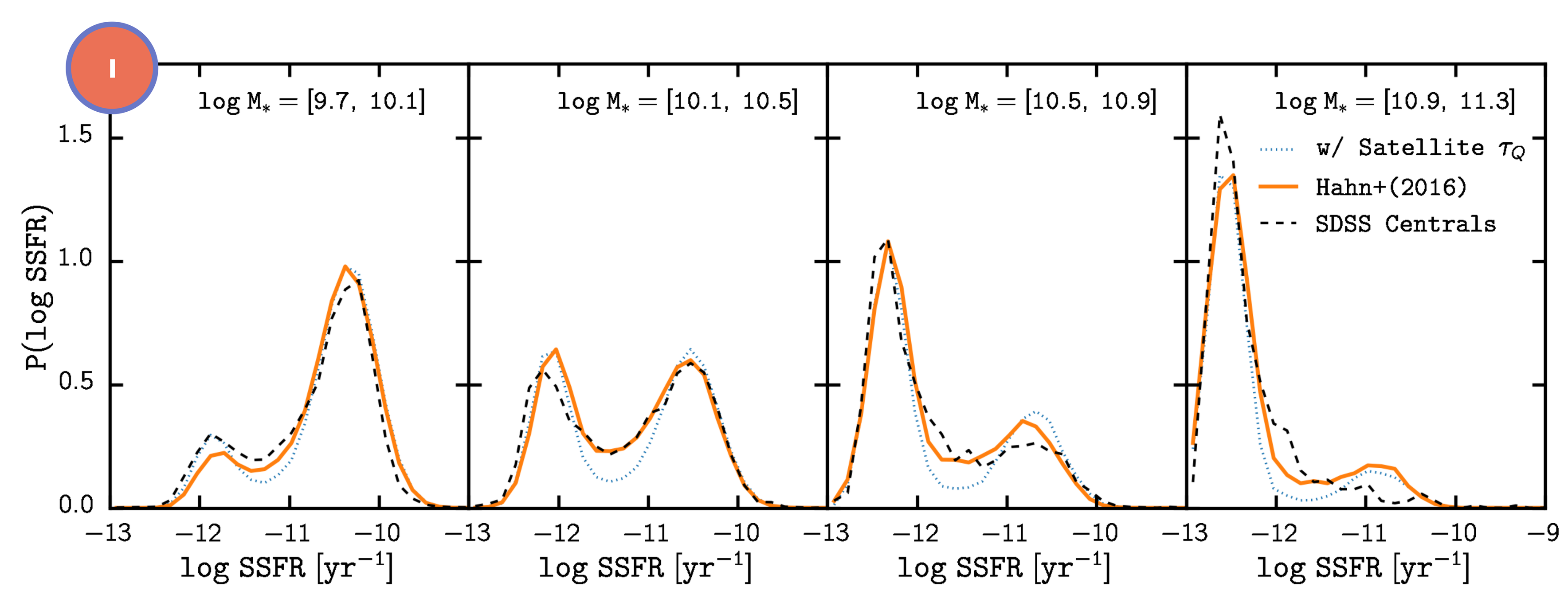
3 With merger and AGN driven quenching fallen out of favor, we find mild tensions between the our central quenching timescale and the timescales of mechanisms that halt the accretion of cold gas (e.g. halo quenching) but good agreement with the timescales of morphological quenching.



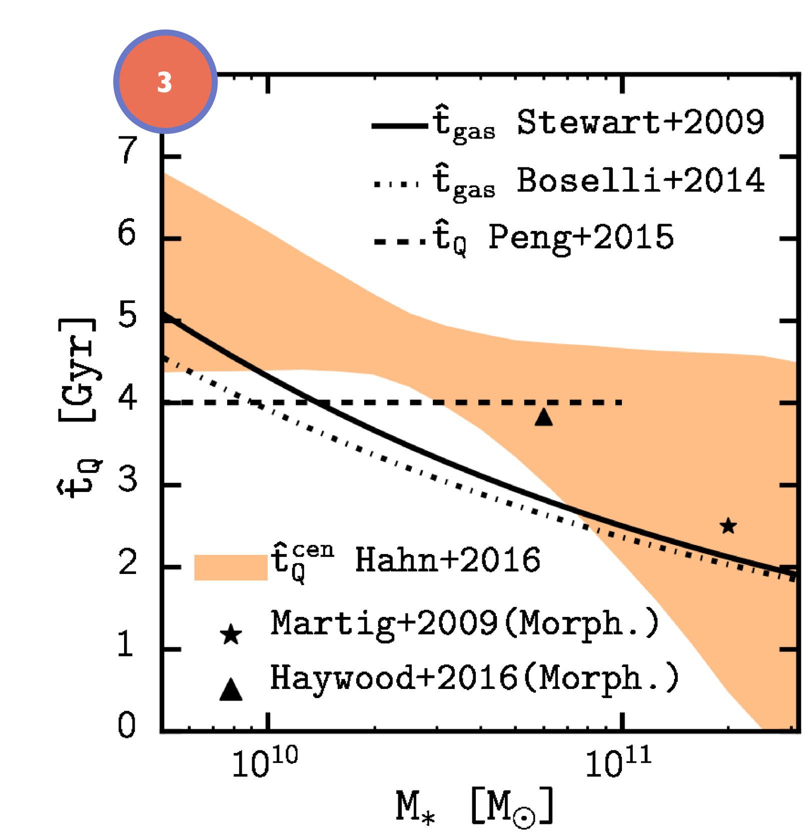
Quenching timescale τ_Q^{cen} of central galaxies

The red points represent the median τ_Q^{cen} of the posterior parameter distributions and faint red lines represent τ_Q^{cen} drawn from the final ABC parameter pool. The satellite quenching timescale of Wetzel et al. (2013) (black dashed) is plotted for comparison.

Our τ_Q^{cen} constraints reveal that central galaxies have a significantly longer τ_Q than satellite galaxies. This suggests that distinct physical processes are responsible for the cessation of star formation in central and satellite galaxies. It also goes to cement the bifurcation of quenching mechanisms into "environment" and "mass" quenching, which observations have long suggested.



Comparison between the SSFR distribution of our model using the median parameter values of the ABC posterior distribution (orange) and the SSFR distribution of the SDSS DR7 central galaxies (black dash). Our model SSFR distribution is in good agreement, especially in the transition (green valley) regions, which the quenching timescale dictates.



Quenching time estimate t_Q^{cen}

Comparison of the central galaxy quenching time estimate, t_Q^{cen}, with quenching time estimates for halo and morphological quenching.

For halo quenching, t_Q is estimated using either gas depletion times derived from gas fraction measurements (Stewart+2009; Boselli+2014) or the Peng+(2015) gas regulation model estimate. For morphological quenching t_Q is taken from the SFHs of the simulated galaxy in Martig+(2009) and the Milky Way in Haywood+(2016)

Overall, halo quenching has mild tension with our results. It quenches star formation faster than the t_Q^{cen} we infer. Although its feasibility for a wider galaxy population is unexplored, morphological quenching is in good agreement with our results.

arXiv:

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