Image credit: SDSS

Unveiling the History of Coma Cluster Galaxies

Matching star formation histories to simulated orbits

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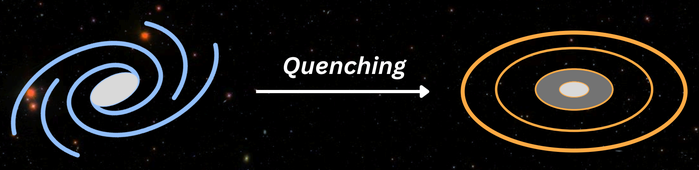
Quenching in Clusters

Galaxy populations in clusters show an increase in quenched (i.e. little to no star formation) galaxies with increasing density (Dressler 1980). However, the exact mechanisms involved in quenching galaxies are not yet well understood. In addition to mass quenching, environmental quenching mechanisms like *starvation* or *ram pressure stripping* (RPS) heat or strip the galaxies of their gas, eventually leading to *overconsumption*. Other galaxies can arrive at infall already pre-processed, having been part of a previous, lower mass host environment.



Here we investigate at what stage in their star formation history galaxies fall into the cluster, how they continue to form stars, and at what point in their orbital history they quench.

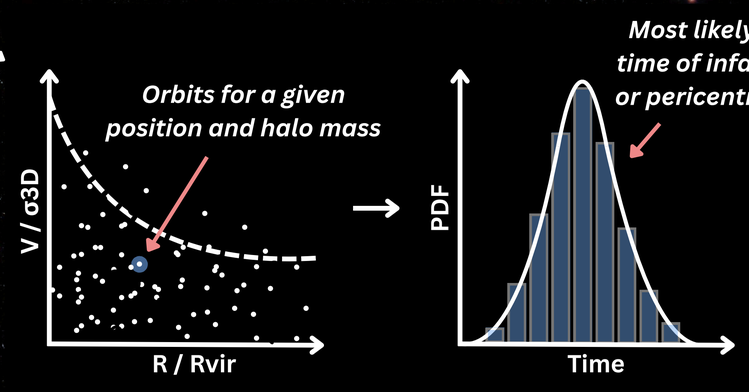
SFHs from Spectral Fitting

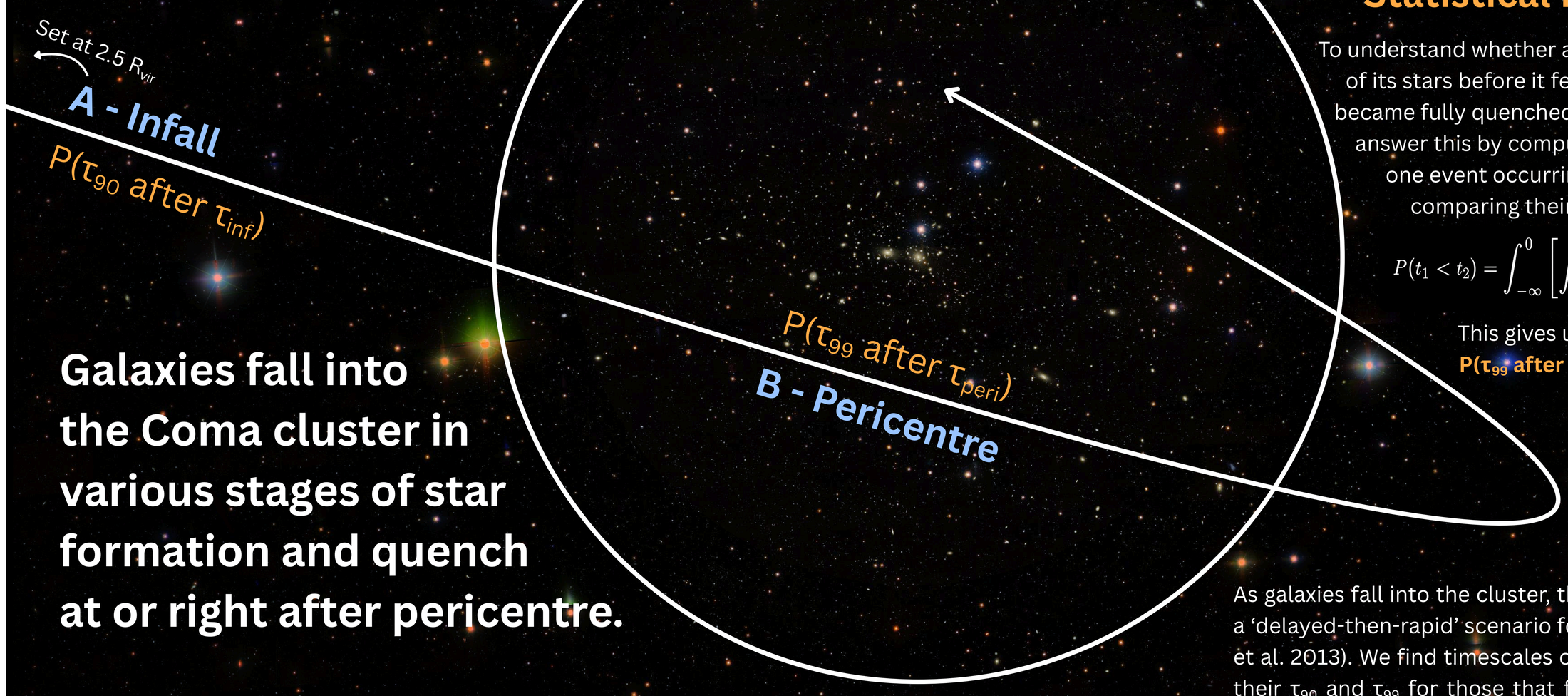
To include both cluster and infalling galaxies, galaxies were selected from SDSS DR8 based on position and velocity, expanding outward up to 3.5 virial radii with respect to the Coma cluster. Following further data selection, we inferred the star formation histories (SFHs) of 672 galaxies using two spectral fitting codes, pPXF (Cappellari 2023) and BESTA (Corcho-Caballero in prep.), using a non-parametric star formation model with E-MILES stellar templates.

Instead of using the full SFHs, PDFs of the times at which a galaxy formed 90% and 99% of its current stellar mass are interpolated, τ_{90} and τ_{99}, comparing these key points against their orbital histories.

Orbital Parameter Distributions

Following the approach of Oman et al. (2021), we traced infalling dark matter haloes over time using a cosmological N-body simulation, providing the time of infall, τ_{inf}, set at 2.5 R_{vir}, and the first pericentre, τ_{peri}, for each halo. Using projected phase space (below, left), these dark matter haloes are tied to an observed galaxy based on their cluster-centric radius & velocity, their halo mass, and their host halo mass. As a result, each observed galaxy has its own orbital parameter distribution (below, right).





Galaxies fall into the Coma cluster in various stages of star formation and quench at or right after pericentre.

Statistical Framework

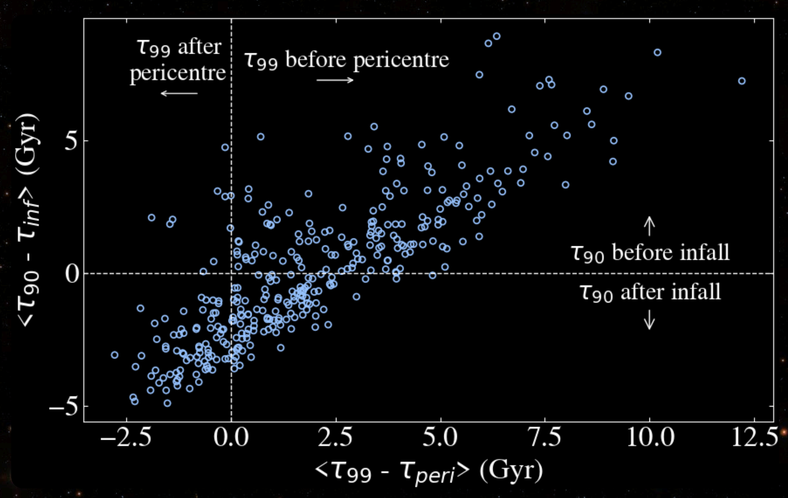
To understand whether a galaxy formed most of its stars before it fell into the cluster, or became fully quenched after pericentre, we answer this by computing the probability one event occurring before another by comparing their full posterior PDFs:

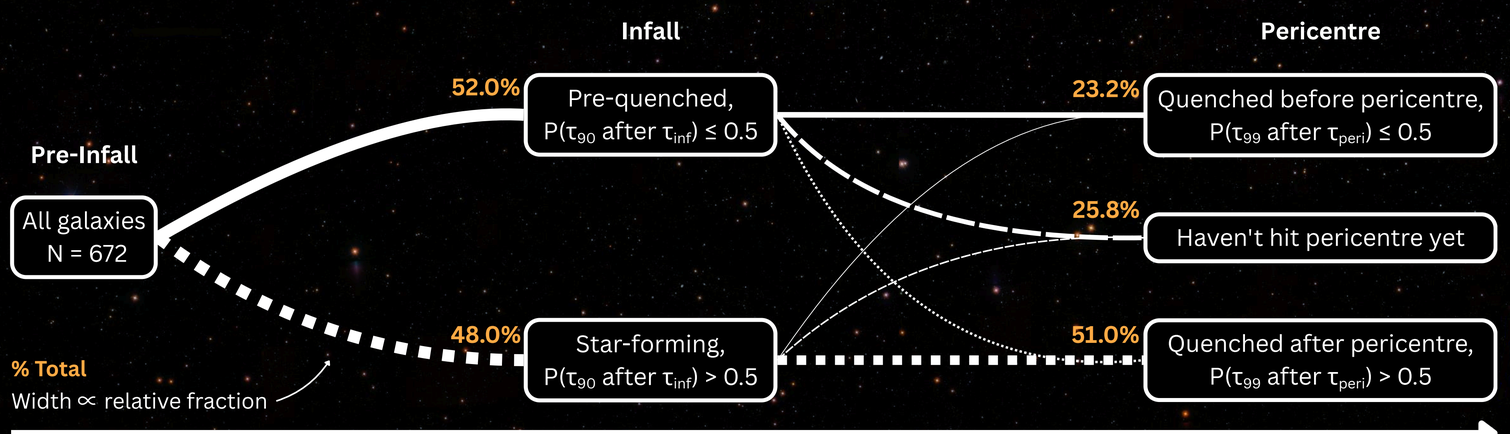
$$P(t_1 < t_2) = \int_{-\infty}^{0} \left[\int_{-\infty}^{\infty} \rho_{t_1}(t)\, \rho_{t_2}(t - x)\, dt \right] dx.$$

This gives us **P(τ_{90} after τ_{inf})** and **P(τ_{99} after τ_{peri})** for each galaxy.

Delayed-then-Rapid

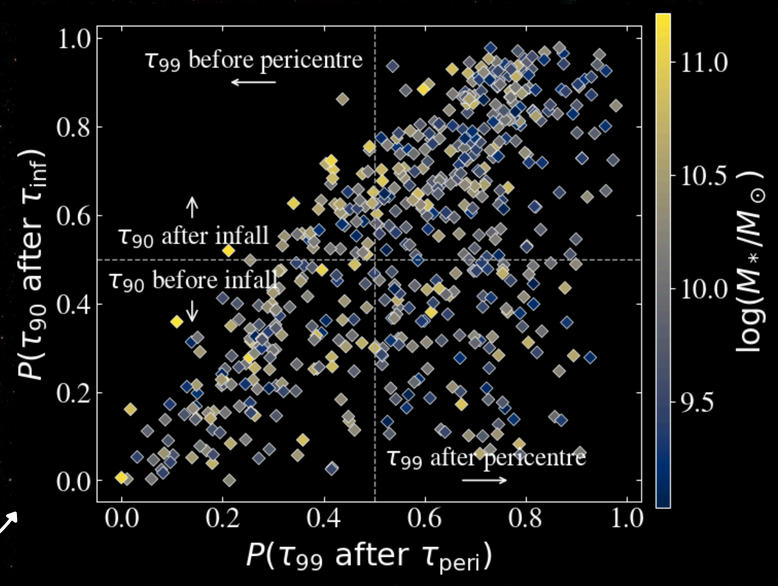
As galaxies fall into the cluster, they likely experience a 'delayed-then-rapid' scenario for quenching (Wetzel et al. 2013). We find timescales of 1 to 2 Gyr between their τ_{90} and τ_{99} for those that formed 90% of their current stellar mass after infall. Overall, most star formation ceases 2 Gyr after pericentre.





Quenching Pathways

We find no single quenching pathway for Coma cluster galaxies. Instead, galaxies fall into the cluster having or not having formed 90% of their current stellar mass in equal parts, likely seeing a mix of direct infallers, pre-processed and post-processed galaxies. Those that arrive at infall pre-quenched are more likely to quench before pericentre. pPXF finds this to be mass-dependent, whereas BESTA (shown) finds no strong mass trend. Overall, both spectral fitting codes agree with each other consistently.



Future Work

Our conclusions are limited by the broad distributions we find, which can be explored further by investigating more clusters with higher S/N spectra, or supplementing with optical and radio imaging to see physical trends.

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References: Dressler (1980), ApJ, 236, 351 - Wetzel et al. (2013), MNRAS, 432, 336 - Cappellari (2023), MNRAS, 526, 3273 - Corcho-Caballero et al. (in prep.)

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