Orbit Deconstruction for Quenching Modelling

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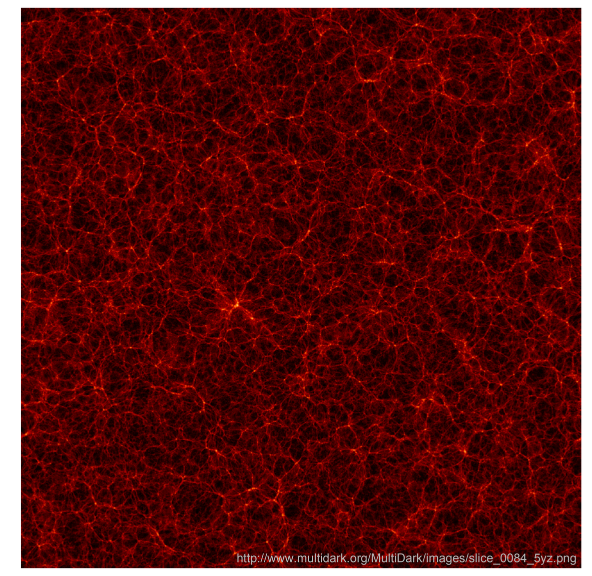
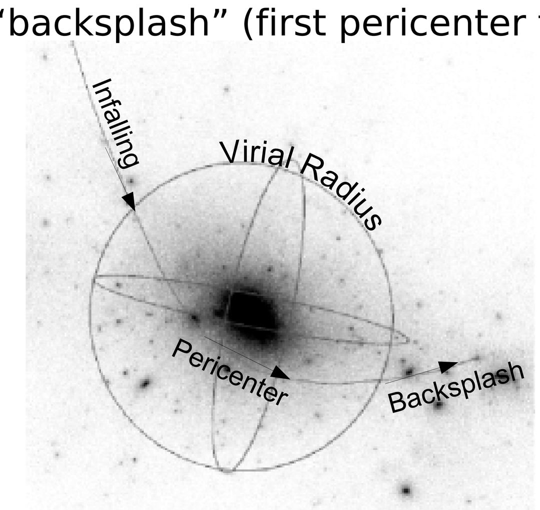
Introduction

- Galaxies in cluster environments are typically more “red and dead” than field galaxies. Due to the dependence on environment, this is usually attributed to an external star formation quenching mechanism [1].
- Typical external quenching mechanisms include tidal stripping, ram pressure stripping and shock-heating [2]. The magnitude of their effect is a strong function of position and/or local density; modelling them therefore requires knowledge of a satellites orbital history.
- While observational data only allows access to 3 coordinates for a satellite (position on the sky and line of sight (LOS) velocity) and limited time evolution, cosmological simulations allow sampling of the full 6D phase space over time.
- Satellite orbits can be split into segments: “infalling” (before first pericenter), “backsplash” (first pericenter to first apocenter) and “virialized” (≥2[nd] orbit).



Above: A visualization of the dark matter distribution in the MultiDark Simulation (Run 1) at z=0.



Left: Schematic of orbital stages of a satellite galaxy near a large cluster. Not shown is the “virialized” stage, which occurs later when the satellite is confined to the virial radius. Credit: [3].

- The (first) backsplash population extends out to ~2.5 r_{vir}. Only 2% of galaxies have a clear second backsplash; the majority are already virialized before this occurs [3].
- Quenching is strongest at pericenter, but is not instantaneous [4]. Detailed orbital tracks are therefore necessary to test realistic quenching models. These can be obtained most readily from cosmological simulations.

Purpose

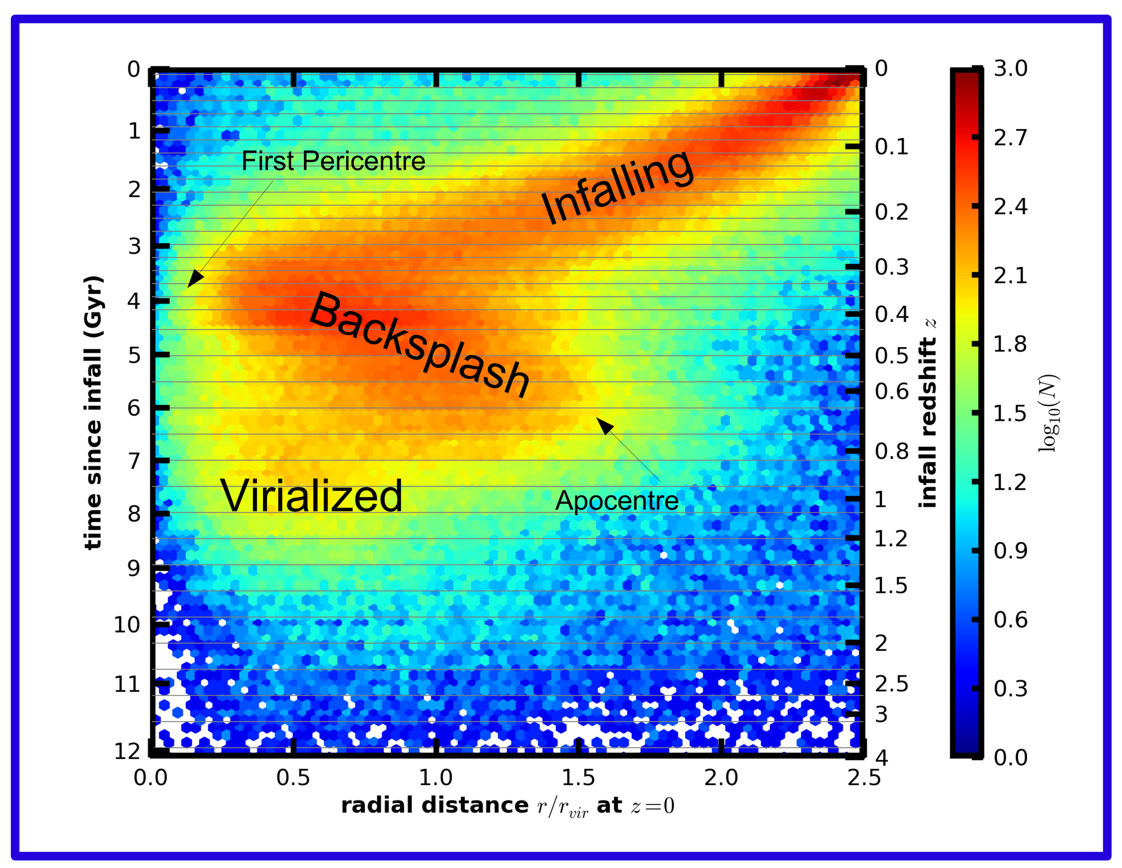
- Define a relation that takes as input the projected host centre-to-satellite distance and the line-of-sight velocity of the satellite relative to the host (observables), and produces as output the time since accretion onto the cluster.
- Present this output as a distribution of possible times weighted by their occurrence in simulation.
- Use these distributions to identify the orbital status of observed satellites: infalling, backsplash or virialized.
- Compare observed satellite star formation rates as a function of orbital status to predictions of quenching models constructed from simulation orbits.

Method

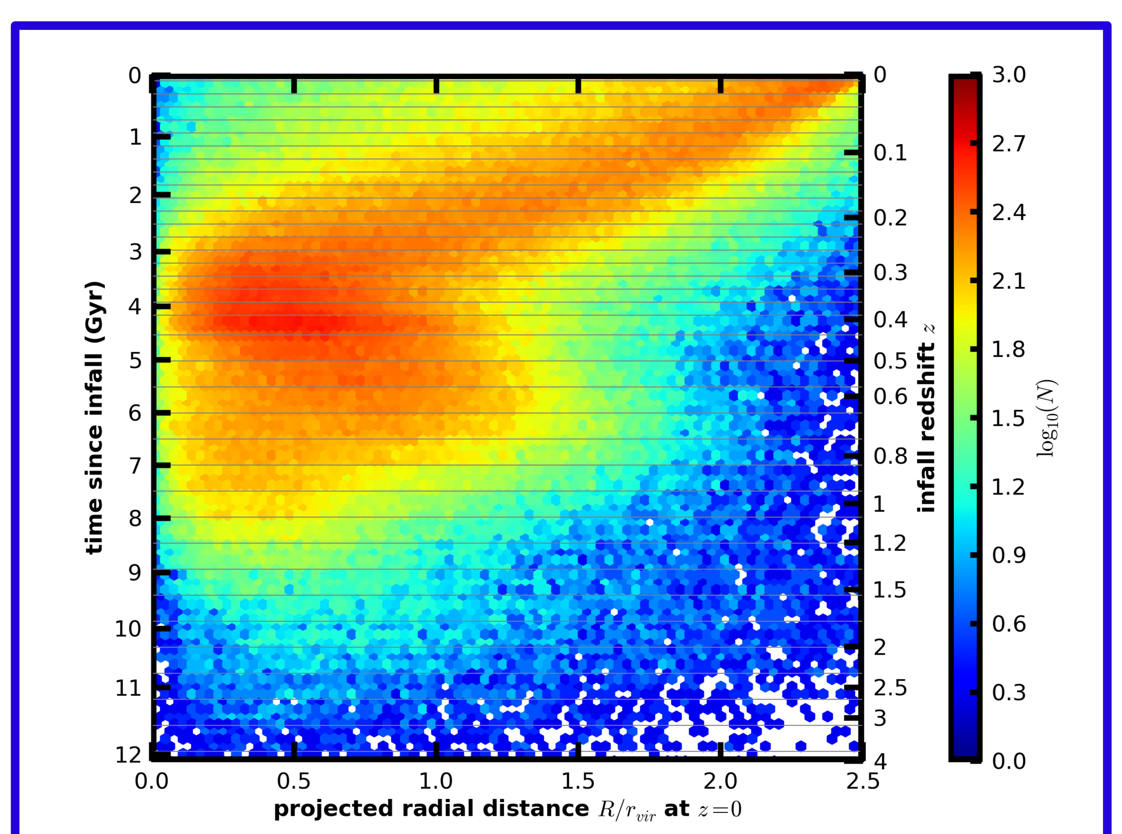
Data	
Simulation	MultiDark Run 1 (BigBolshoi)
Box Length	1 $Gpch^{-1}$
Number of Particles	2048^3
Resolution	Mass: $8.7\times10^9\ M_{\odot}h^{-1}$; Force: 7kpc
Halo finding	ROCKSTAR [5]
Merger Trees	Consistent Trees [6]
Satellites Selected	~570,000

- A *cluster* is defined as a halo with $M \geq 10^{14} M_{\odot}$. Halos that are within 2.5 r_{vir} of a cluster at z=0 are selected.
- The *infall time* is defined as the earliest time at which a satellite was within 2.5 r_{vir} of its z=0 host cluster's progenitor halo. (Note this is a somewhat unusual definition of infall).
- The distribution of infall times is sampled in bins in phase space (r / r_{vir} and v_r / σ) to give a probability distribution function (PDF) of infall times as a function of phase space coordinates.
- Projected (i.e. observable) coordinates are also considered.

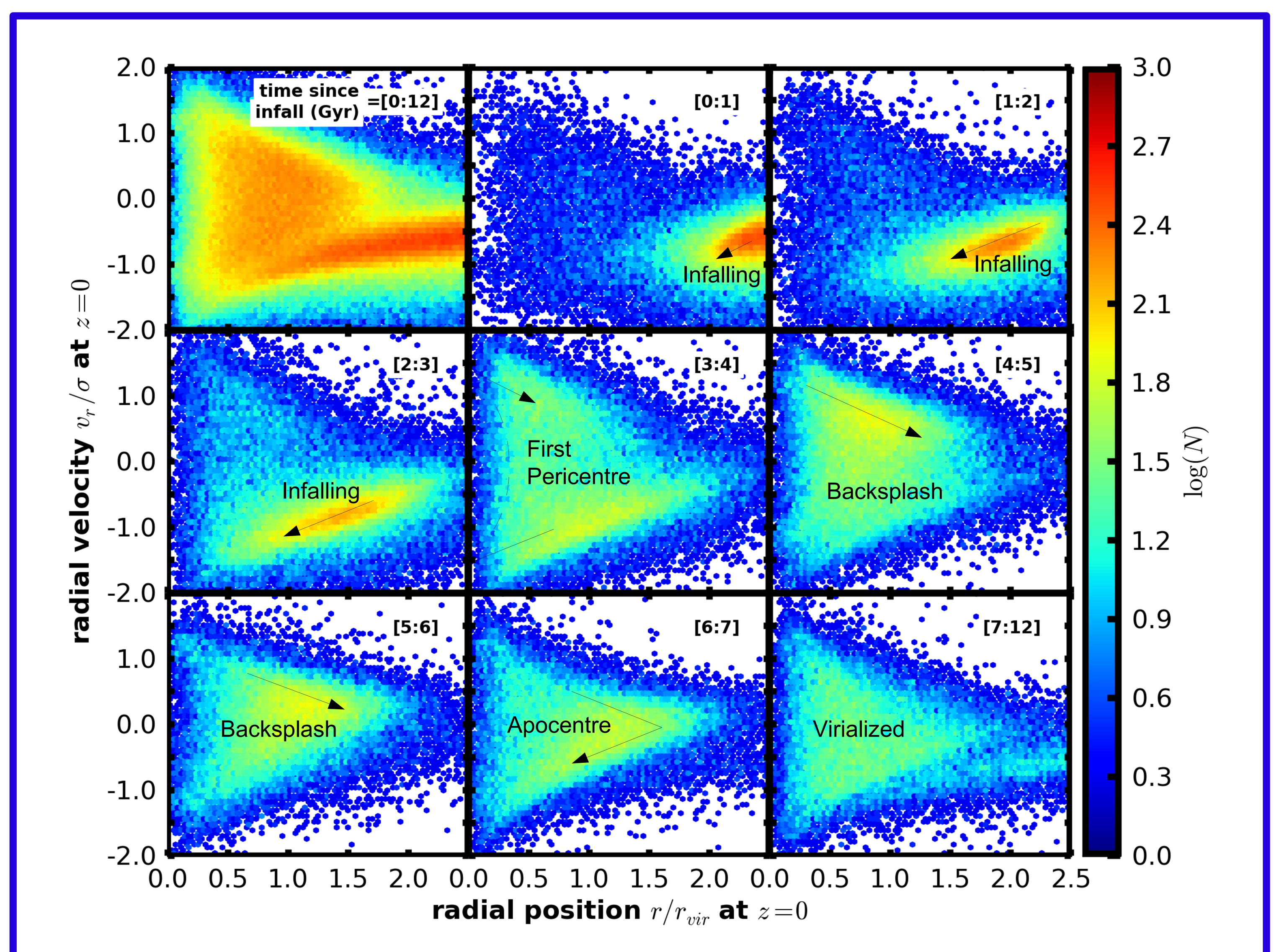
Results



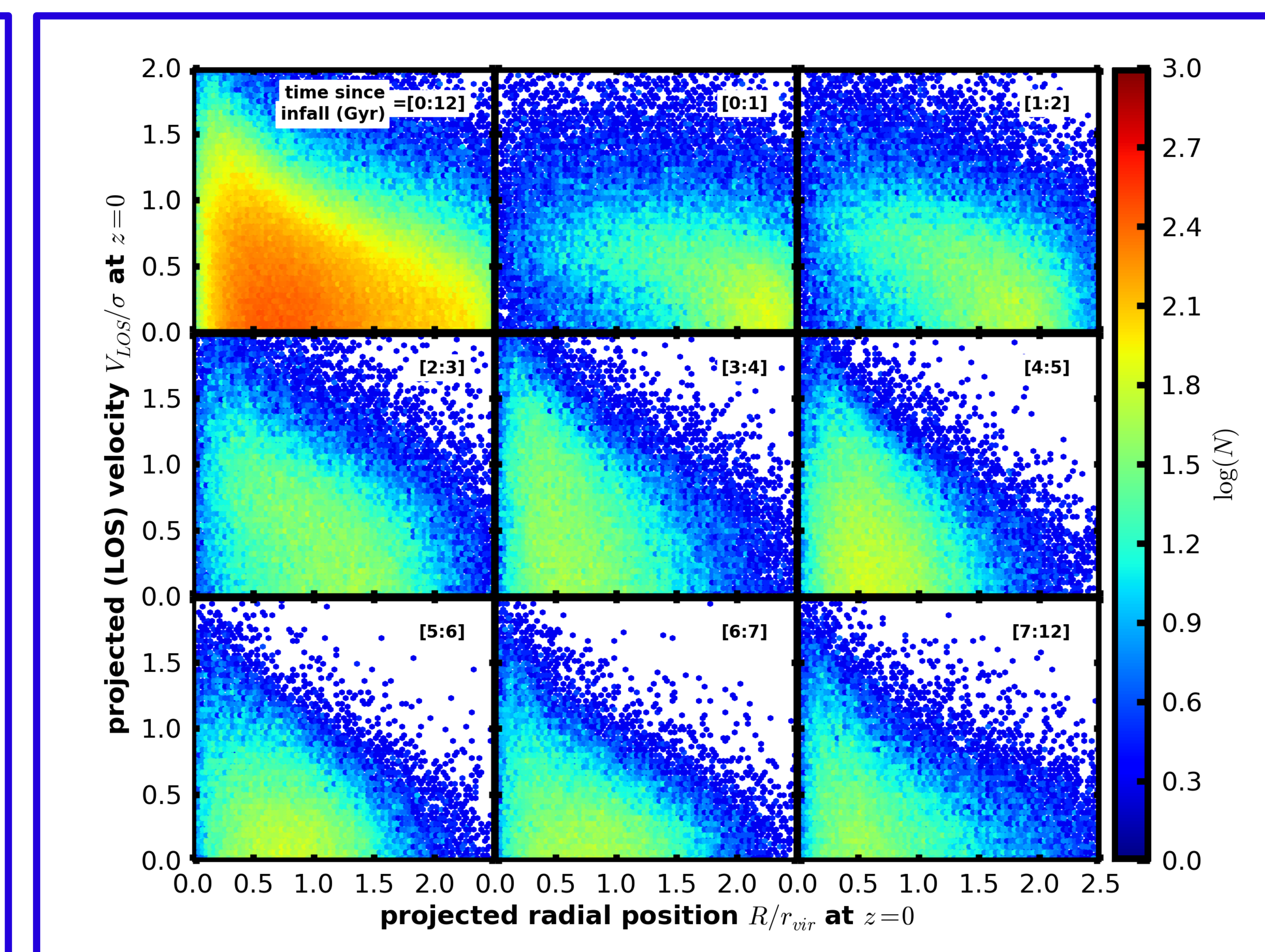
Left Top: Abundance of satellites in bins of cluster infall time (defined as first inward crossing of 2.5 r_{vir}) and radial distance from cluster centre at t=0. In the interval t=0 to t~3.5 the “infalling” population is visible, composed of satellites that have not yet experienced a pericentre passage. From t~3.5 to t~6 the “backsplash” population is visible, composed of satellites that have passed pericenter once and are approaching apocentre (t~6). The “virialized” population (t>6) are on a second or subsequent orbit. Gray horizontal lines illustrate the simulation time resolution.



Left Bottom: As *left top* but using radial distance from cluster centre projected along one axis of the simulation box (simulating coordinates accessible in observations). This widens the distribution of halos somewhat in the horizontal direction, but the same trends are clearly visible. **Wide spread in infall times at some radii makes separating populations in an observed sample somewhat difficult.**



Near Right: Panels correspond to bins by satellite infall time, as labelled (most bins are 1 Gyr, first panel shows all bins stacked). Each panel shows the current (z=0) distribution of satellites in phase space. Different satellite populations (“infalling”, “backsplash”, “virialized”) occupy distinct regions of phase space.



Far Right: As *near right* but using radial distance from cluster centre projected along the one axis of the simulation box and velocity projected along the same axis (again simulating coordinates of an observed system). **Populations are better separated in phase space than in the radial coordinate alone.**

Future Work

- The infall time PDFs will be used to construct semi-analytic models of star formation quenching.
- Physical mechanisms such as tidal stripping, shock heating and ram-pressure stripping will be considered and modelled with a dependence on orbital history (directly available from simulation).
- Observable coordinates will be used to obtain models with predictive power; the orbital history of an observed galaxy can be inferred (at a statistical level) from its phase space coordinates using the PDFs.
- The effects of halo pre-processing (group membership before cluster membership) on quenching will also be examined.

References

[1] Dressler, A., 1980, ApJ, 236, 351
[2] Boselli, A., Gavazzi, G., 2006, PASP, 118, 517
[3] Gill, S. P. D., Knebe, A., Gibson, B. K., 2005, MNRAS, 356, 1327
[4] Mamon, G. A., Mahajan, S., Raychaudhury, S., 2011, Environment and the Formation of Galaxies: 30 Years Later, 135
[5] Behroozi, P. S., Wechsler, R. H., & Wu, H.-Y. 2011a, ArXiV e-prints
[6] Behroozi, P. S., Wechsler, R. H., & Wu, H.-Y. 2011b, ArXiV e-prints