KITP : Co-evolution of the Cosmic Web and Galaxies across Cosmic Time Conference @ UCSB

Tracking Halo Orbits and Their Mass Evolution around the Large-scale Filaments

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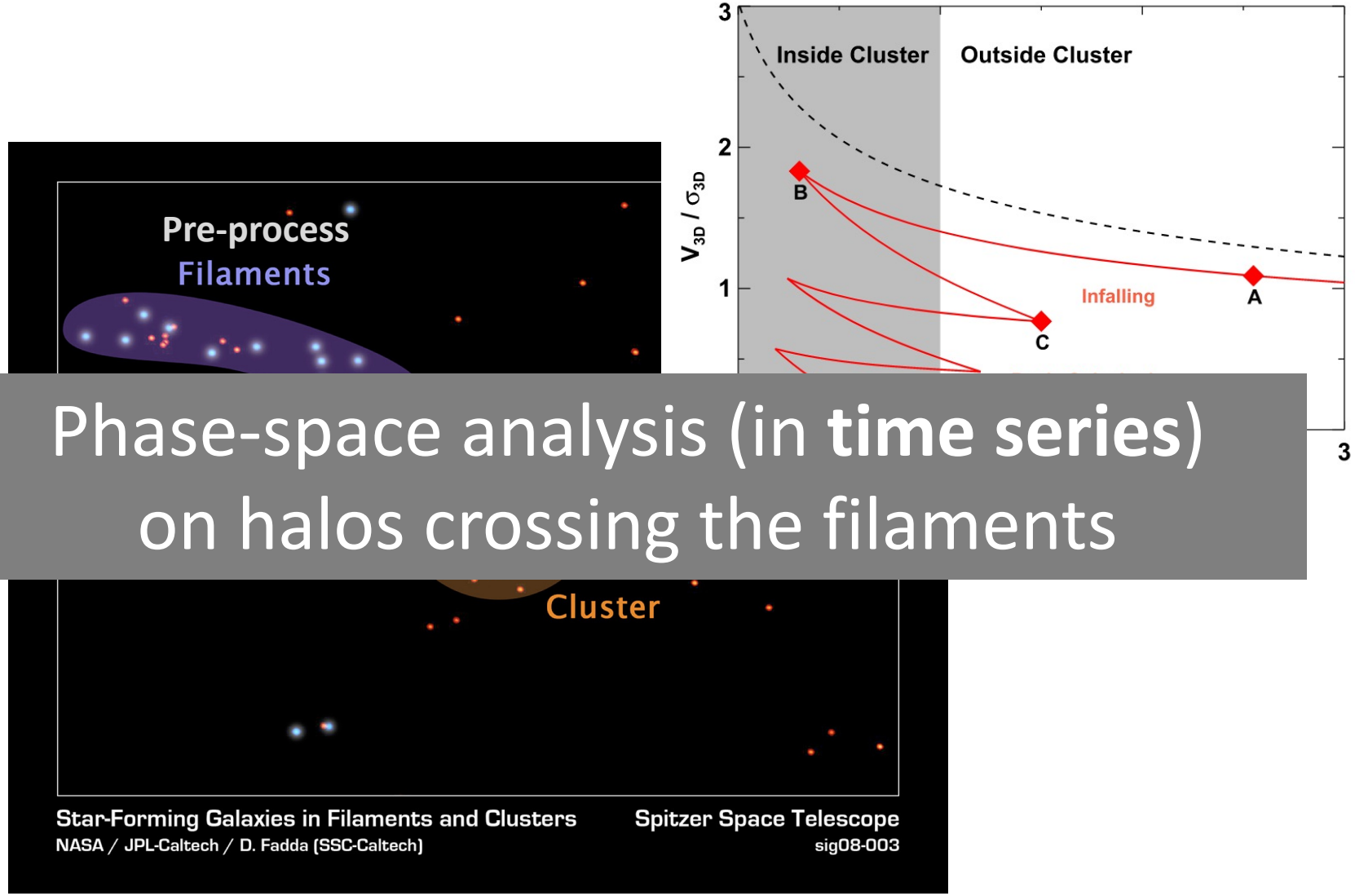
1. Motivation

Rhee et al. 2017

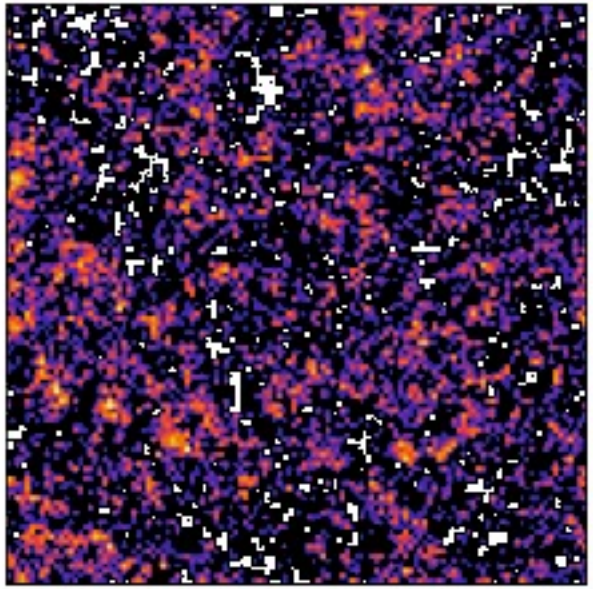


Phase-space analysis (in **time series**) on halos crossing the filaments

2.1. Simulation Data

N-Cluster Run (by Korean Astronomy and Space science Institute)

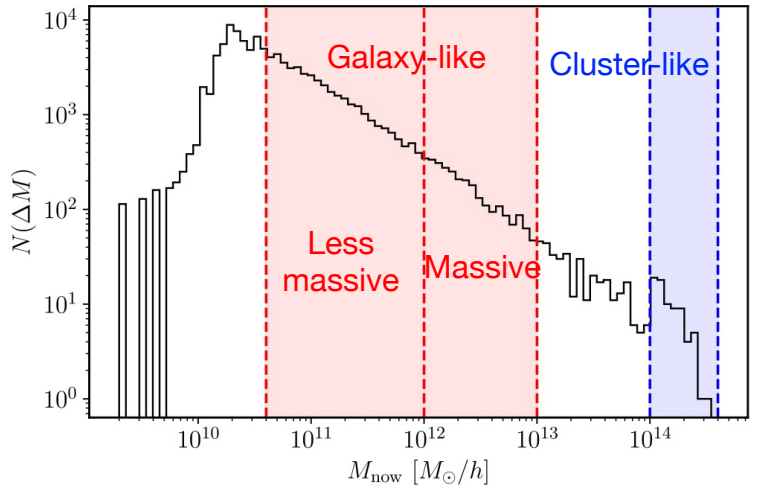
Code	Gadget-3 (Springel 2005)
Cosmological Parameters	$\Omega_\Lambda = 0.7$ $\Omega_M = 0.3$ $H_0 = 68.4\ \mathrm{km\ s^{-1}\ Mpc^{-1}}$ $\sigma_8 = 0.816$ $n = 0.967$
Box Size	$120\ \mathrm{Mpc}$
Mass Resolution	$1.072\times10^9 M_\odot/h$
# of Initial Conditions	64



2.2. Structure Identification

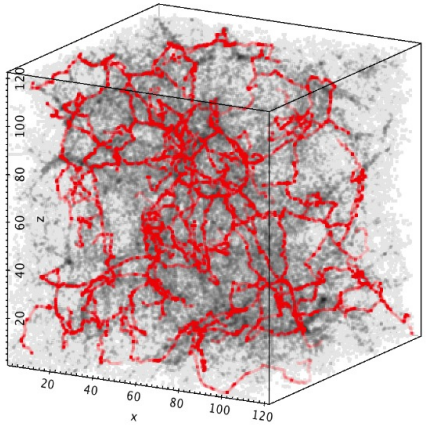
AMIGA Halo Finder (Knollman&Knebe 2009)

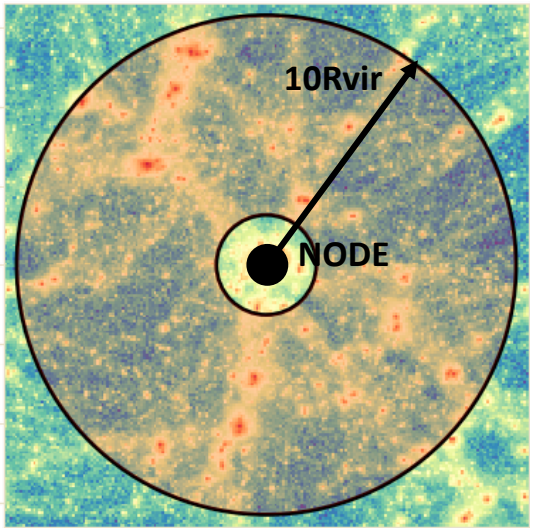
- Halo finding algorithm using grid hierarchy constructed from density calculation
- Halos with $M/M_{\odot} < 4\times10^{10}$ are eliminated for halo structure stability
- Halos with $10^{13} < M/M_{\odot}$ are eliminated because they may correspond to galaxy groups or clusters



DisPerSE (Sousbie 2011)

- Extracts robust large-scale filamentary structures based on dark matter particle density distribution
- Run on particle data around cluster centers

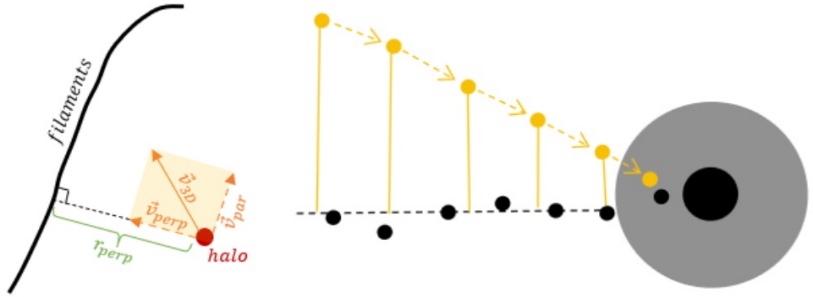


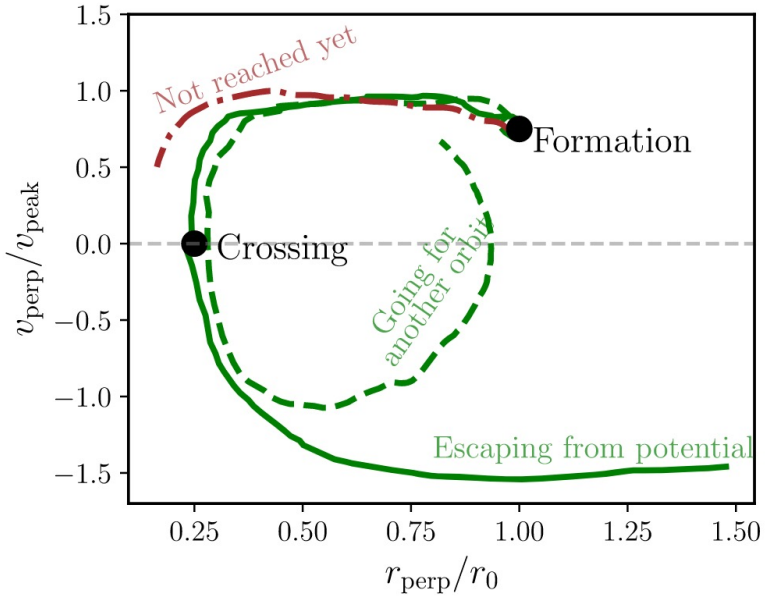


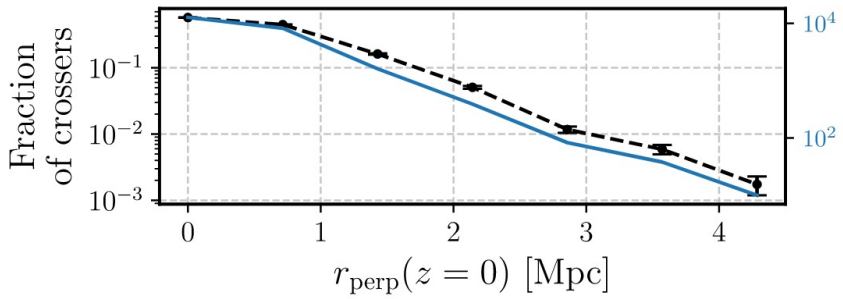
3.1. Trajectories in the Phase-space

Perpendicular Method

- Tangential line to the filaments from a halo at $z = 0$
- Assumes the position of filament structures doesn't change severely
- Perpendicular velocity is positive when a halo is approaching to the filaments

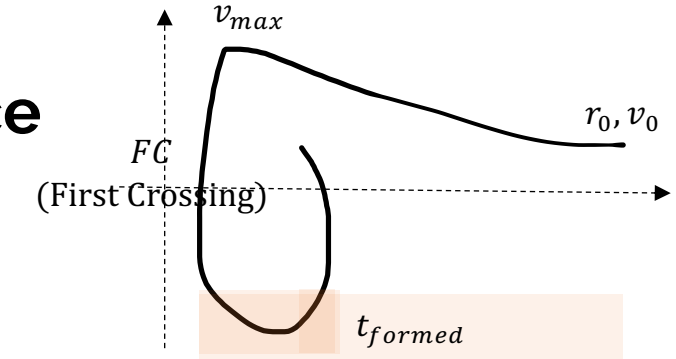






3. Results

3.1. Trajectories in the Phase-space

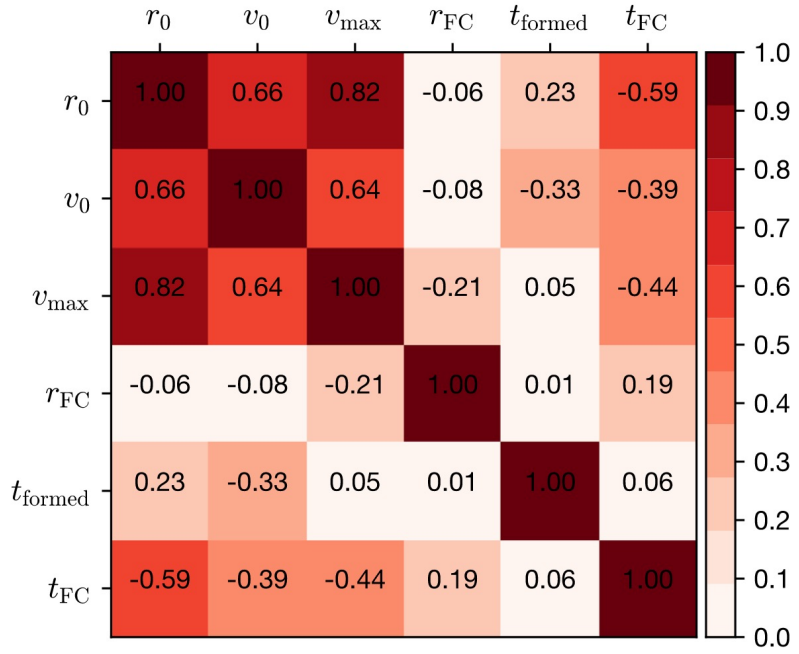


Parameters Defined

- Parameters representing a trajectory in the phase-space

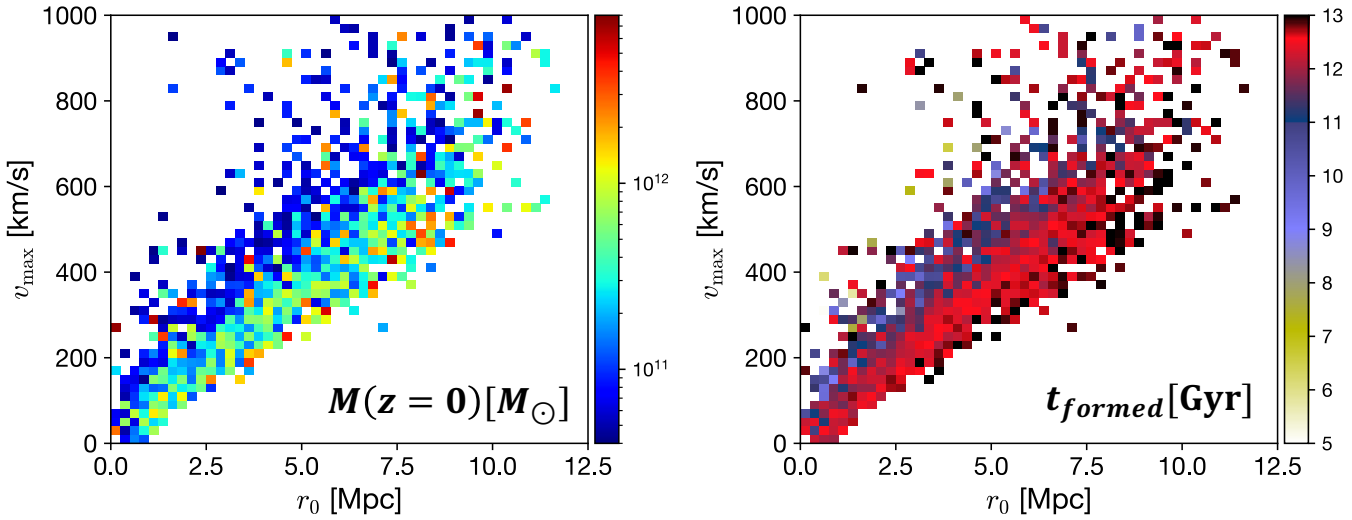
Parameter	Description
r_0	Initial r_{perp}
v_0	Initial v_{perp}
v_{max}	Maximum v_{perp} before the first crossing
r_{FC}	r_{perp} at the first crossing
t_{formed}	Time since formation
t_{FC}	Time since the first crossing

- Pearson Correlation Coefficients $r_{ij} = \frac{\sigma_{ij}^2}{\sigma_i \sigma_j}$
- Inner shells are more accelerated outwards than outer shells are (Sheth & van de Weygaert 2016)



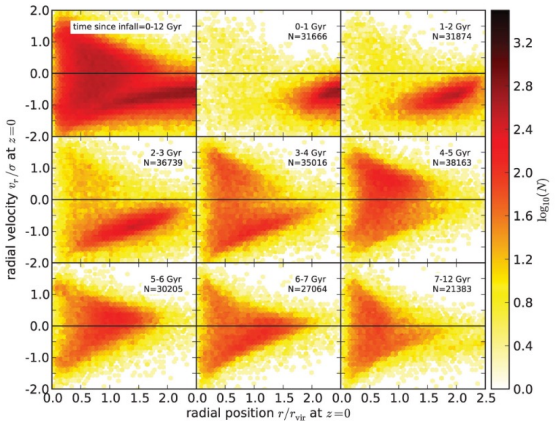
3.1. Trajectories in the Phase-space

r_0-v_{max} Relation

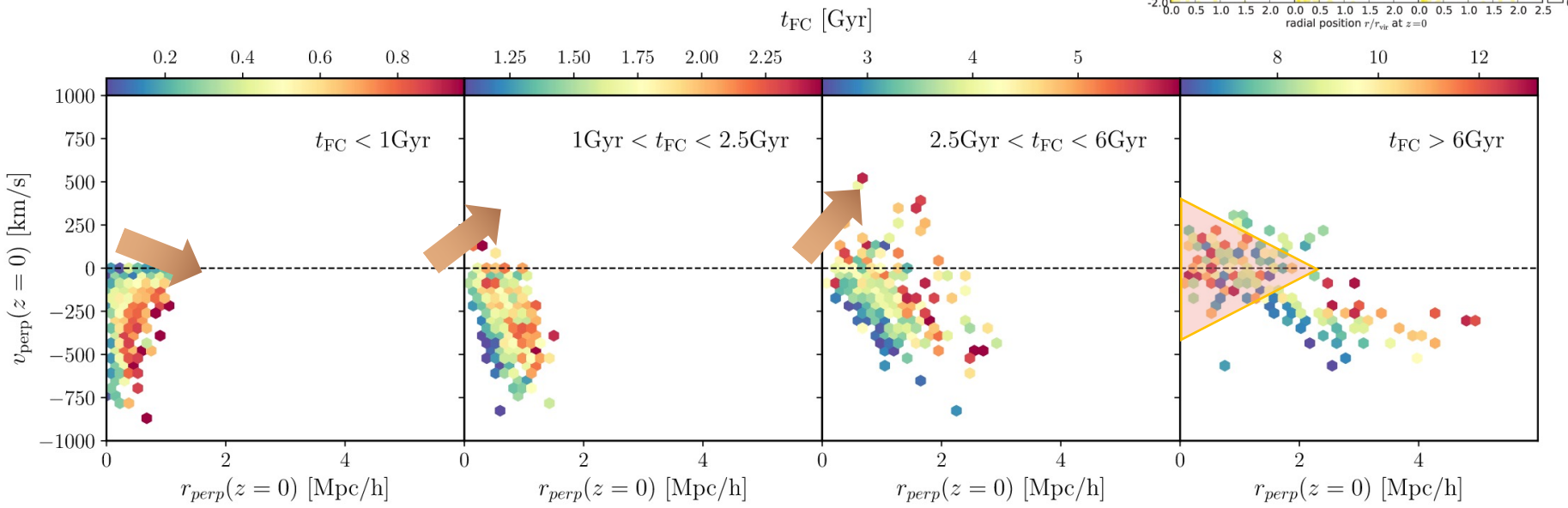


- Massive halos tend to form earlier and have lower velocities for a *given* r_0.
  - The density field at their formation time was not grown much.
  - They may have gone through a rapid growth phase in the cosmic history.

3.2. Virialization of Halos



Phase-space Diagrams with t_{FC} Binning



- t_{FC} gradients in 1st~3rd panels vanish in $r_{perp} < 2Mpc$ region in the last panel
- Still visible in $r_{perp} > 2Mpc$ region

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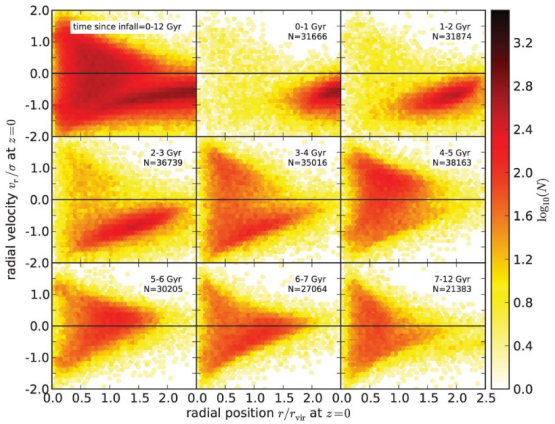
3. Results

3.2. Virialization of Halos



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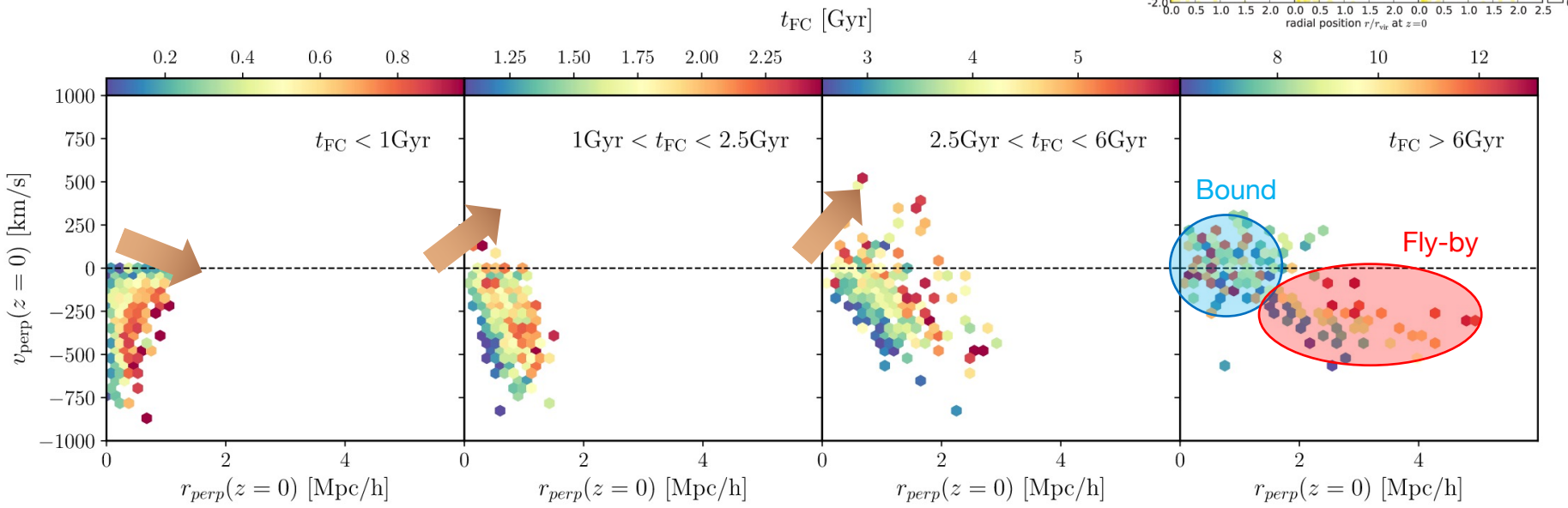
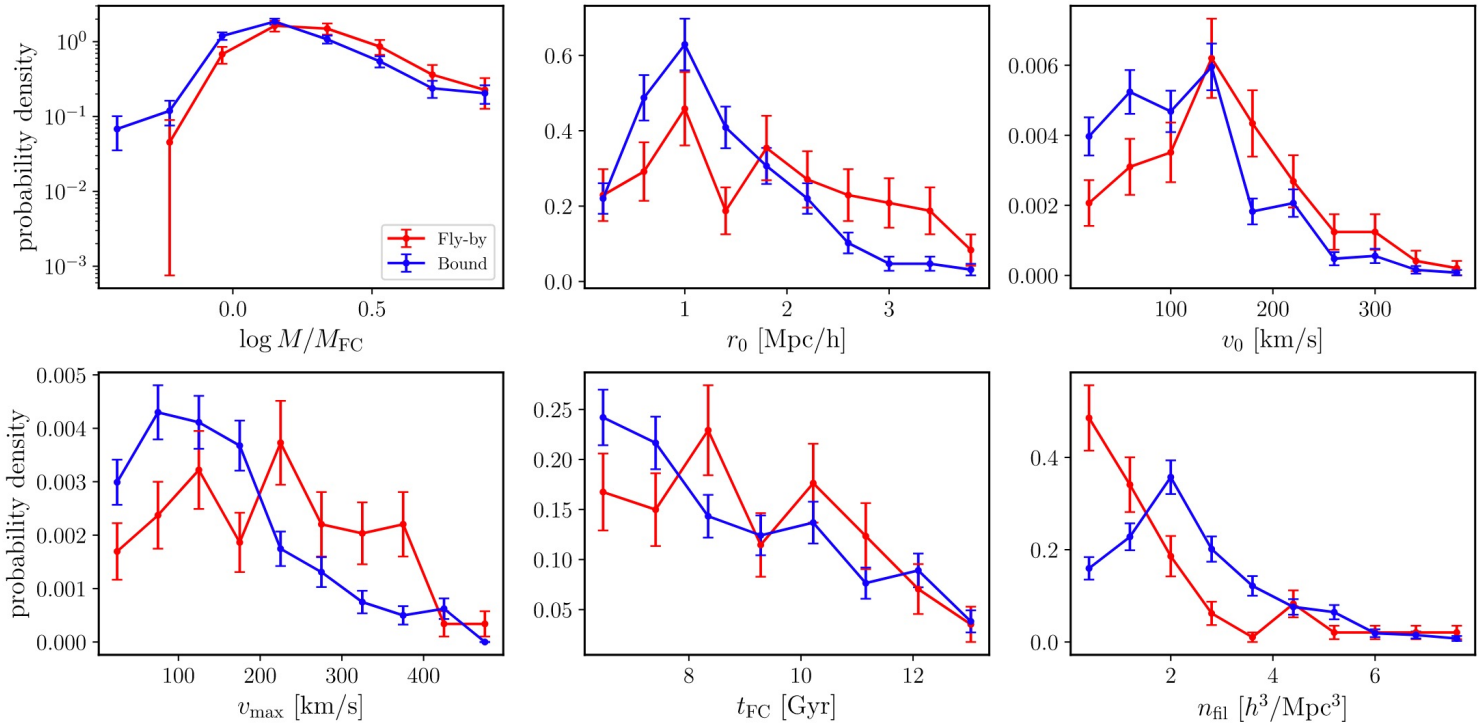


- t_{FC} gradients in 1st~3rd panels vanish in $r_{perp} < 2Mpc$ region in the last panel
- Still visible in $r_{perp} > 2Mpc$ region

3.2. Virialization of Halos

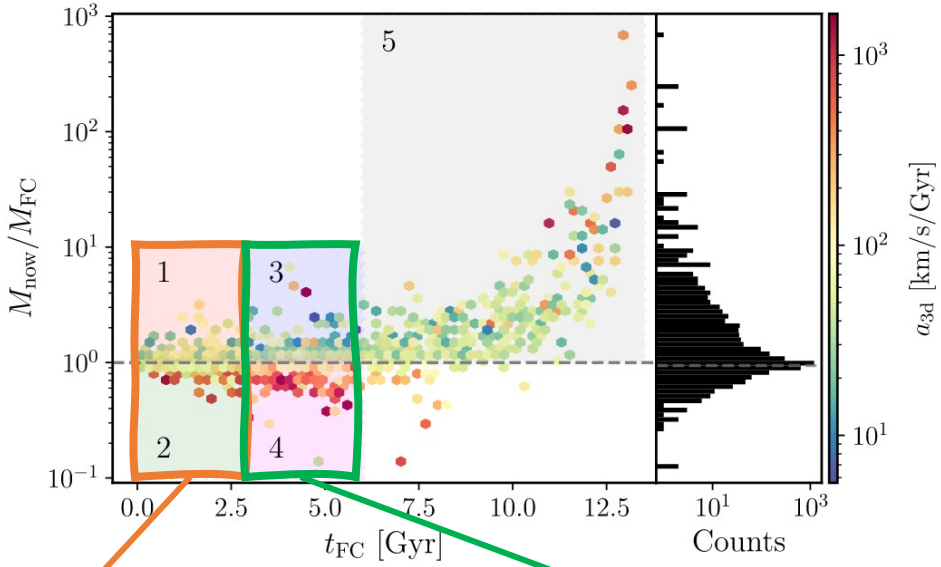
Comparison between *Bounds* and *Fly-bys*

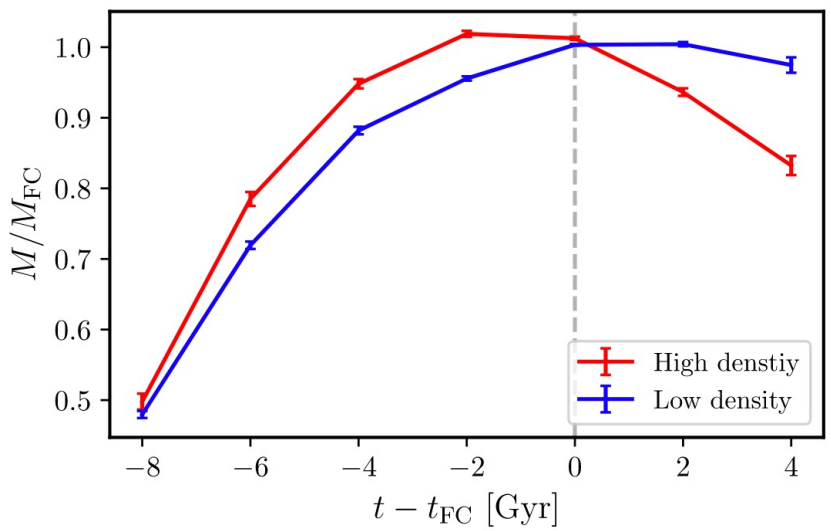


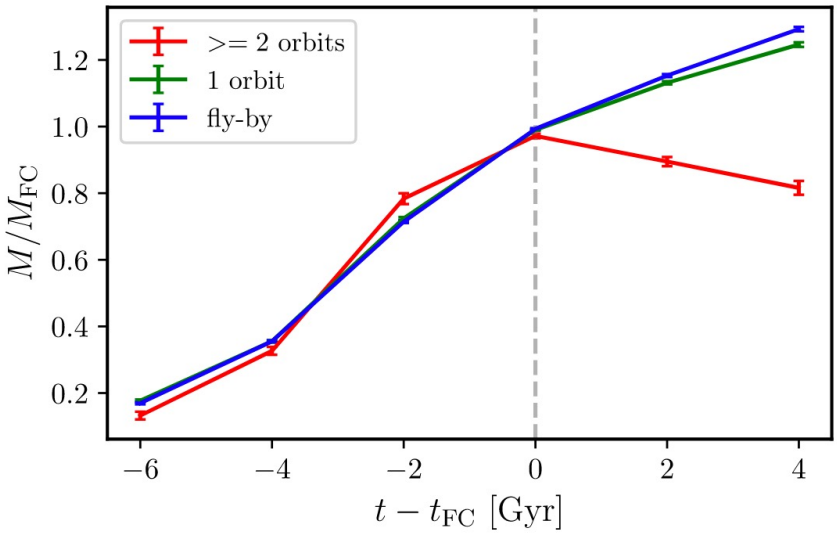
- Fly-bys are tend to be **ancient crossers**, **formed farther** from the filaments(thus higher velocities) and in the **lower density** environments.
- Mass evolution of bound objects may depend on environments.

3. Results

3.3. Mass Evolution of Halos





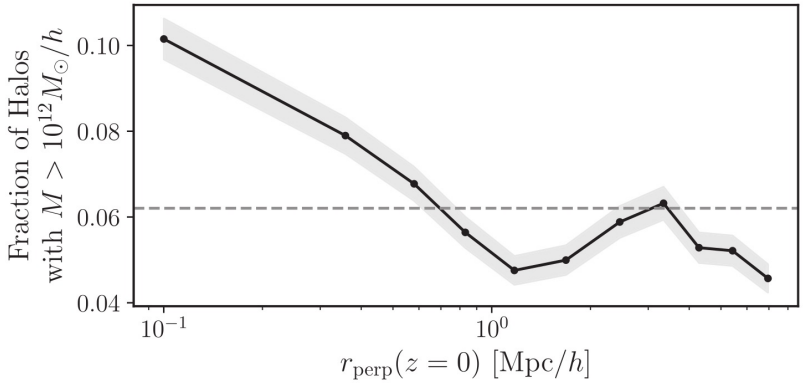


3. Results

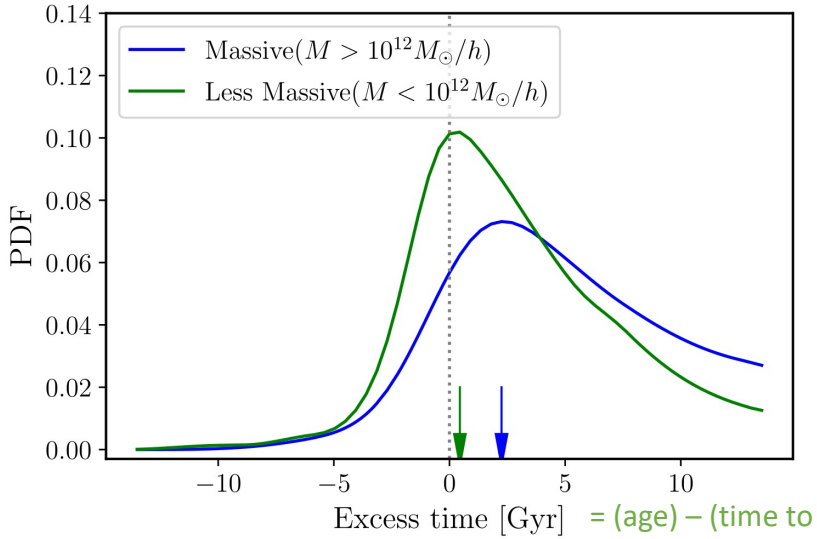
3.4. Mass Segregation

$M/M_{\odot} > 10^{12}$

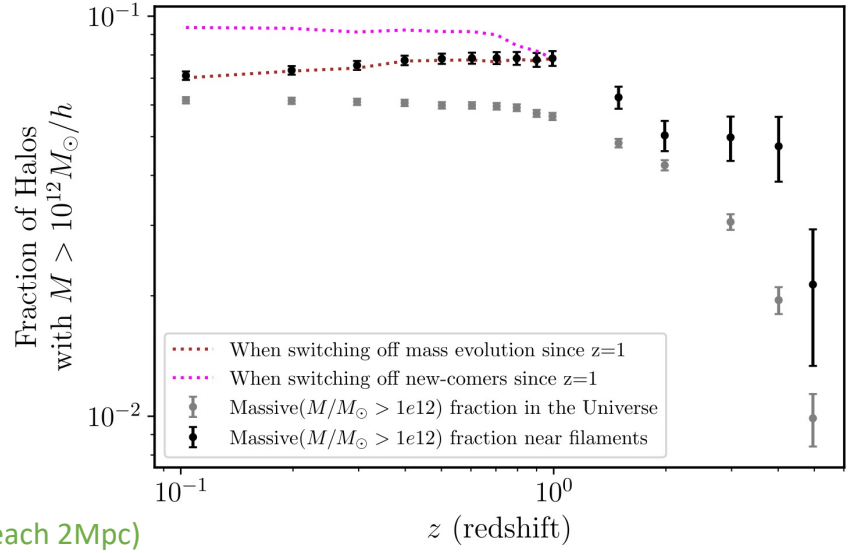
Massive halos arrive earlier, less massive later



- The fraction of massive halos is lower when farther from the filaments
- Massive *crosser* halos lose their kinetic energy and sink in(consistent with observation)

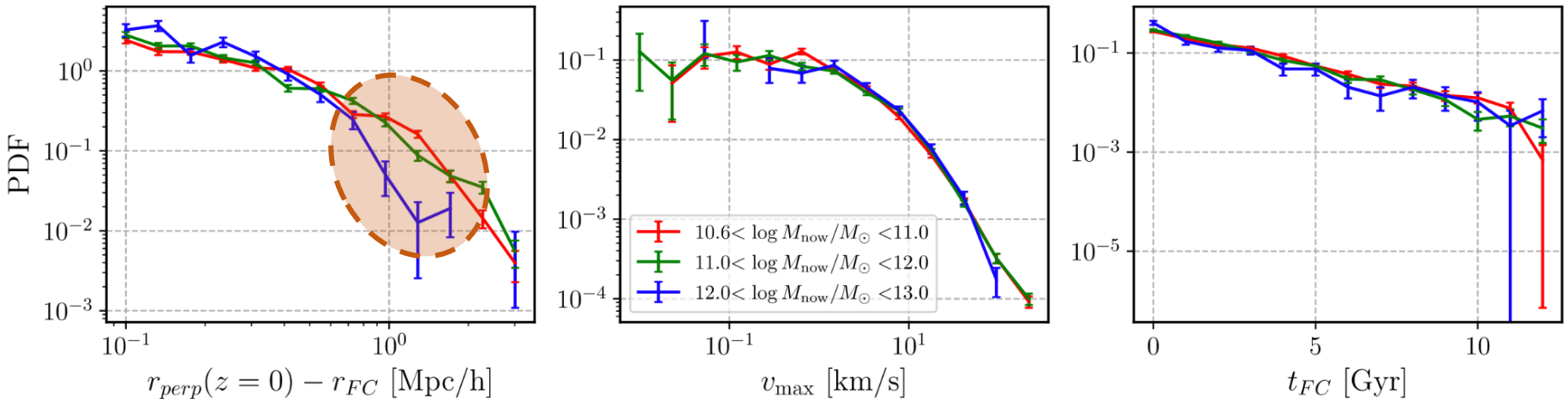


= (age) – (time to reach 2Mpc)



3.4. Mass Segregation

Dynamical Friction plays a role



- For crossers…because their mass segregation can be mixed up with their orbital motion
- Without the effect of velocity and time since infall, most massive halos are suppressed to stay closer to the filaments after the infall.

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SUMMARY

1. Halos show a similar trajectory in perpendicular phase-space.

2. Halos are virialized in filament environments after at least 6 Gyr since the first pericenter crossing.

3. Halos grow in mass as they approach filaments, and will lose mass if the environment is harsh enough.

4. Mass segregation of halos around the filaments is mostly caused by massive halos approaching faster than less massive ones, and dynamical friction plays a role for crossers.

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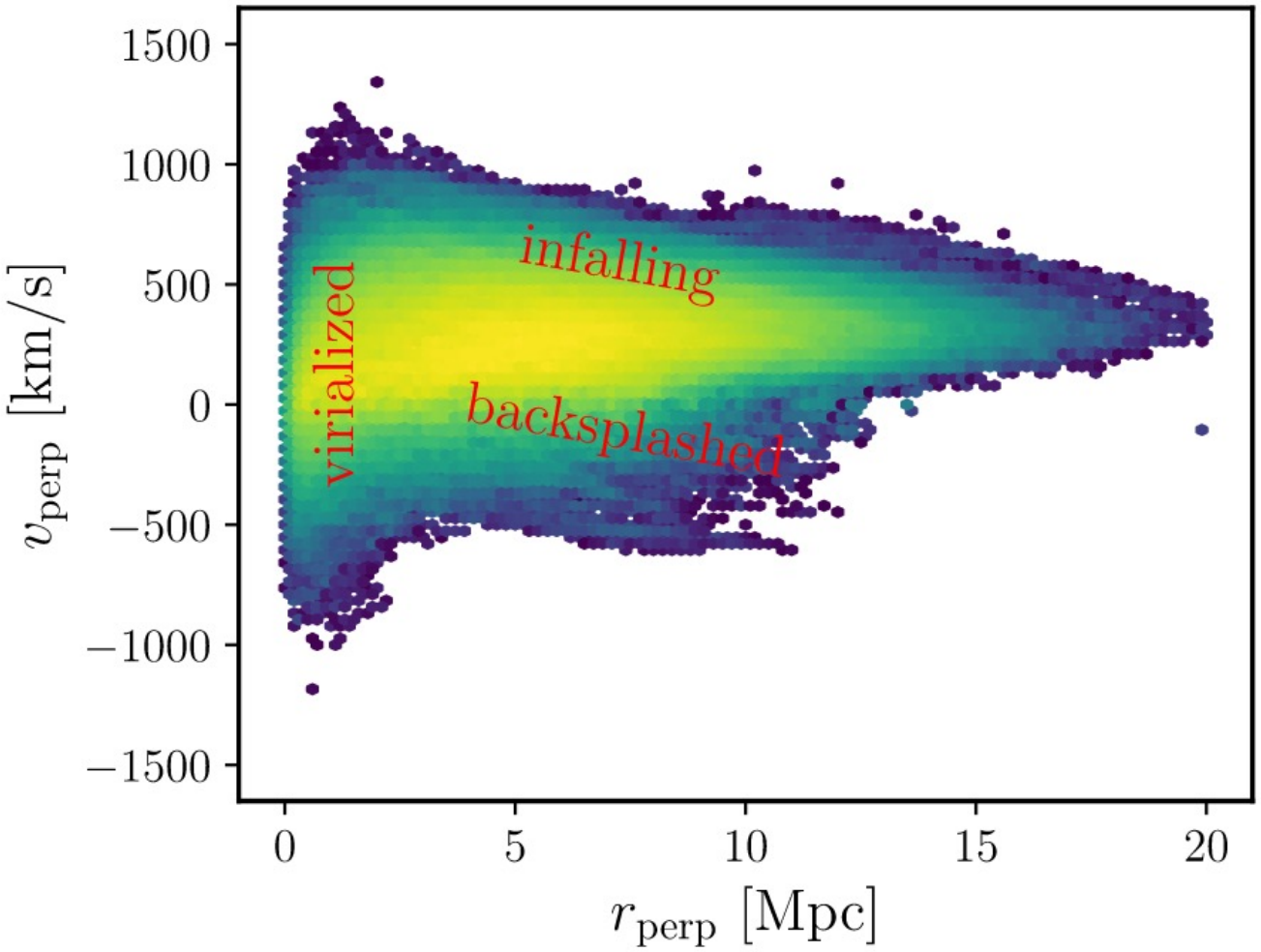

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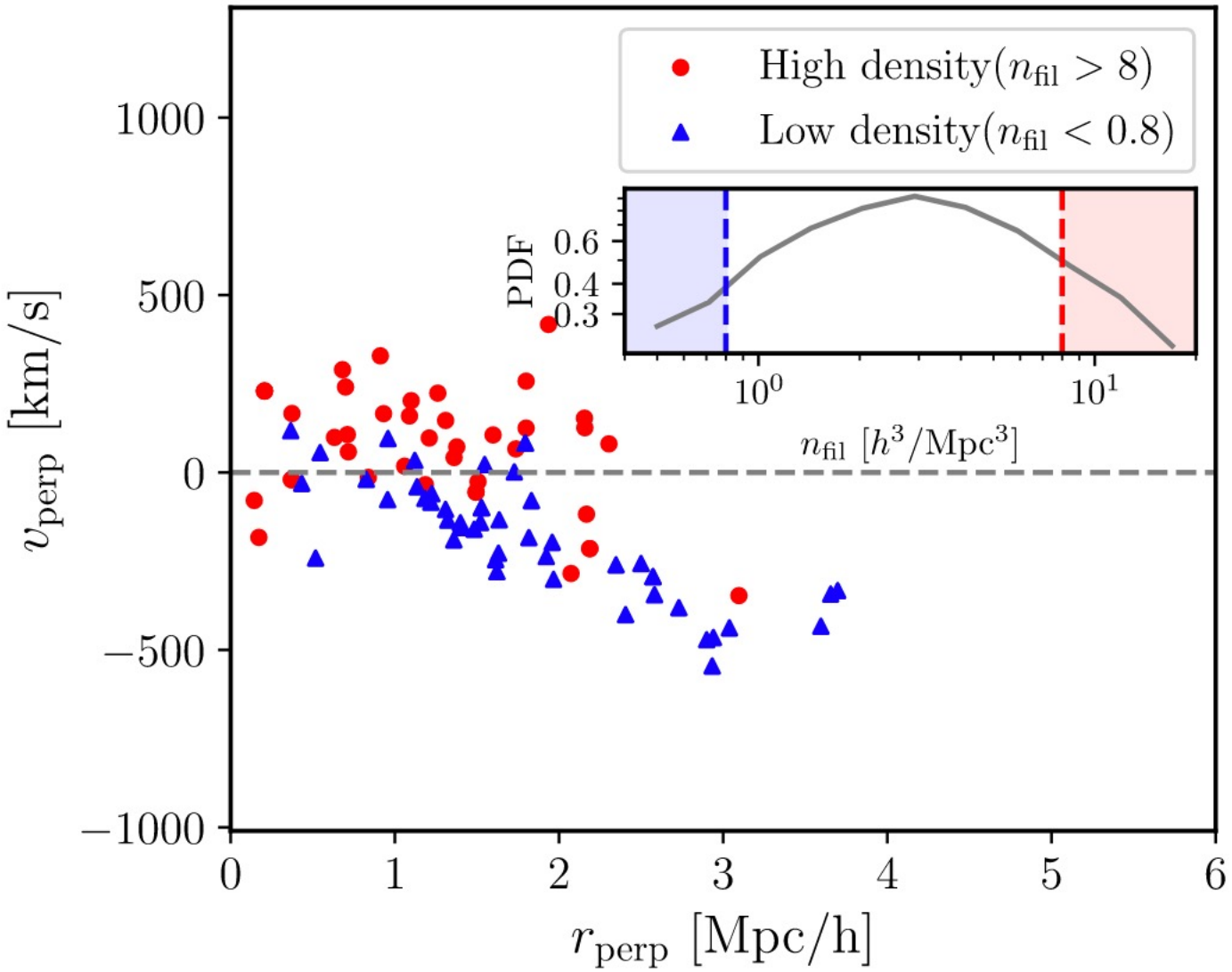

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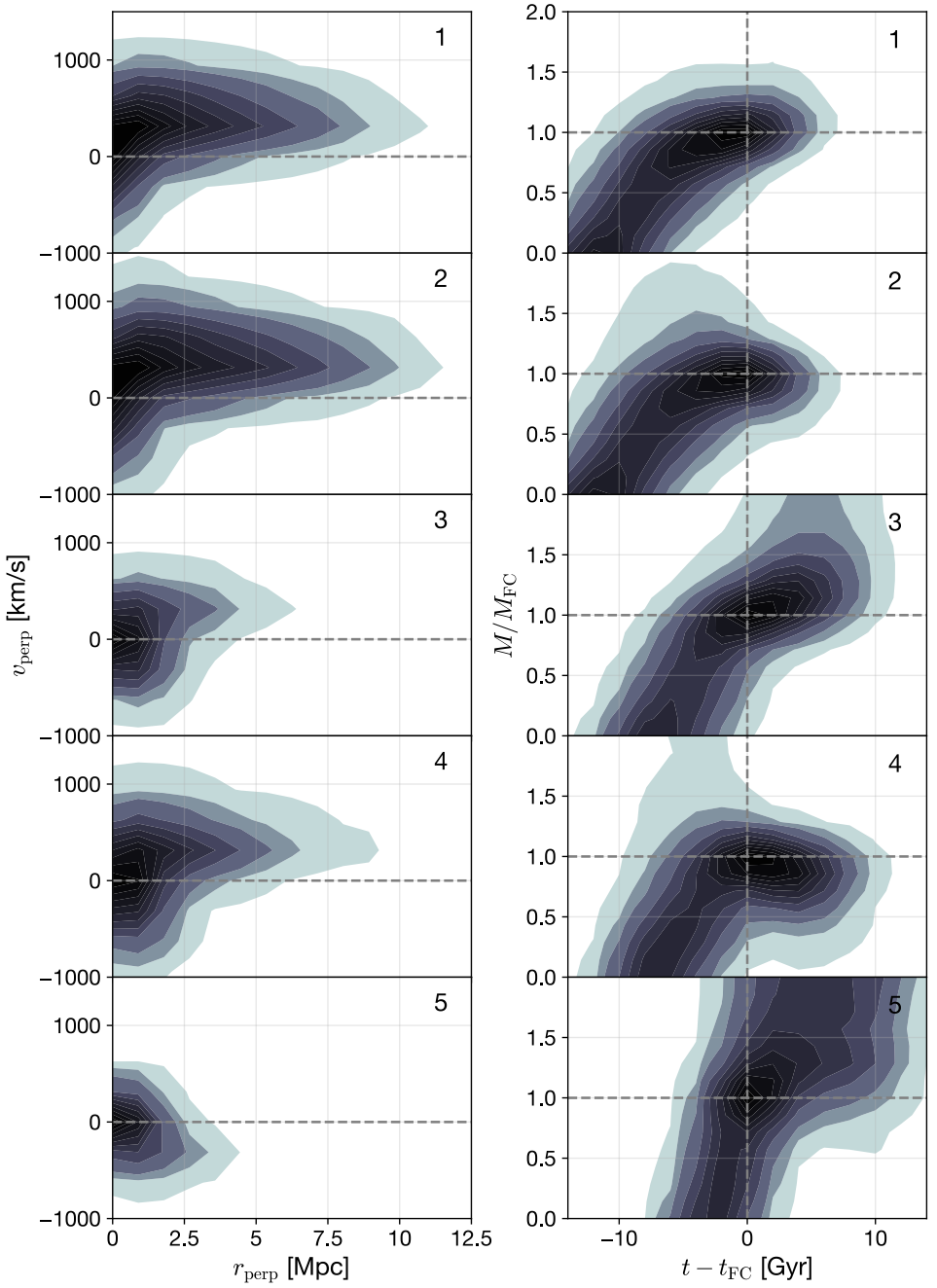

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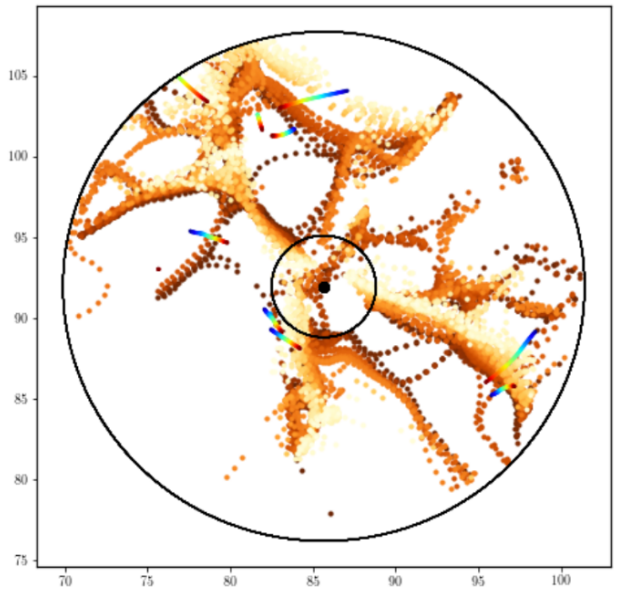

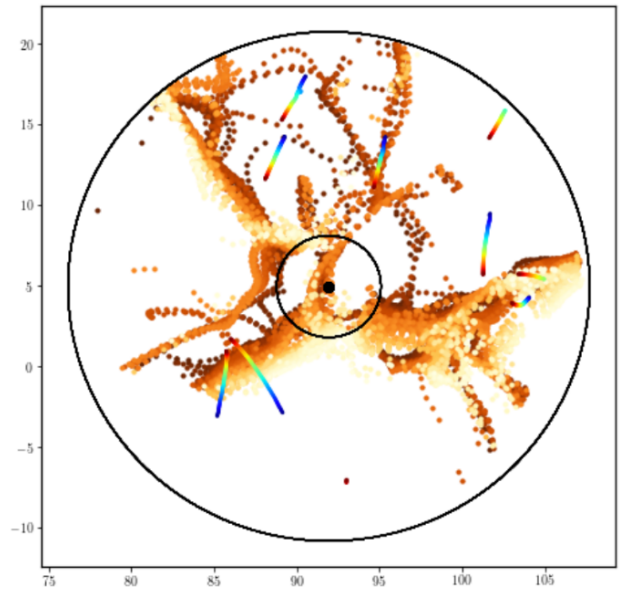

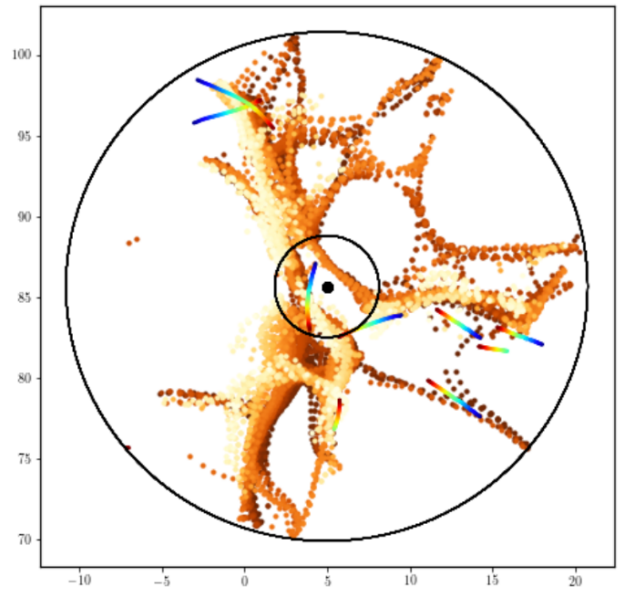

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