Unraveling the causal effect between dark matter halos and their environments Genetically modifying a universe's initial conditions

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- Splicing replaces particles outside of a selected region in the initial conditions by another random field
- Allows to re-simulate the same region while systematically changing the environment
- Can be used to test causal effects between structures (my work: halo+filament)

Initial conditions



(Units are arbitrary)



Environment



proto-halo patch





Overlay the fields







Recombination needed to

- Make boundary smooth and differentiable
- Make resulting spliced field as compatible with ACDM as possible



Environment





Spliced field



Density

I have extended splicing to the potential field

Sets the initial tidal field and linear evolution of AM



Halo-filament spin alignment



Halo-filament spin alignment

 \vec{J}

Halo

Filament



Halo-filament spin alignment





Halo-filament spin alignment The current approach using large volumes







How do similar-mass halos align to their main filament?

large volume = large sample of halos

Can we measure an alignment signal on the scale of a single halo?



Systematically splicing a halo closer to a filament

- Run two volume simulations (50 Mpc)
 - serve as repositories for potential halo and filament candidates
- Identify one Milky Way-mass halo and one large filament
- Splice the halo across a range of distances to the filament (9 configurations in total)
- Run zoom simulations for each halo





Systematically splicing a halo closer to a filament







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Systematically splicing a halo closer to a filament









Measuring the spin alignment

Parallel

~ 15 %



Initial evolution is the same

• We find a misalignment signal of over 15% at present day

Reminder

Only difference is the environment

Linear predictions are the same for all configurations!





Getting the complete picture



We can look at the deviation of different halo guantities from the mean

• Mass, virialization, and maximal velocity are the same

 Morphology and orientation vary significantly

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filament



Getting the complete picture



We can look at the deviation of different halo guantities from the mean

- Mass, virialization, and maximal velocity are the same
- Morphology and orientation vary significantly
- For this halo, spAM and spin have been impacted as well

filament



Conclusions

 Splicing can be used in controlled numerical experiments to test for causal effects between structures

dark matter halo by at least 15% into a mis-aligned configuration

Morphology is also significantly impacted, leaving properties like mass, viral radius, and maximal velocity unchanged

• We show how, through splicing, the non-linear tides from a filament torques a

