Lagrangian Transfer

Josh Borrow ICC, Durham University

Daniel Angles-Alcazar CCA

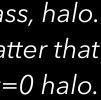
Mentors

Romeel Dave Edinburgh



- Introduction; a short history of cosmological simulations
- Physical motivation
- What is a Lagrangian Region?
- Gas: where did it come from, where did it go?
- Conclusion

In white, the region where the gas comes from for a z=0, 10^{11} solar mass, halo. In red/purple, we see the Lagrangian region defined by the dark matter that will end up in the z=0 halo.



Back in the day...

- Everything was easy!
- Forces are all attractive (i.e. only gravity)
- Dark matter follows a relatively simple path to it's final resting place at z=0.

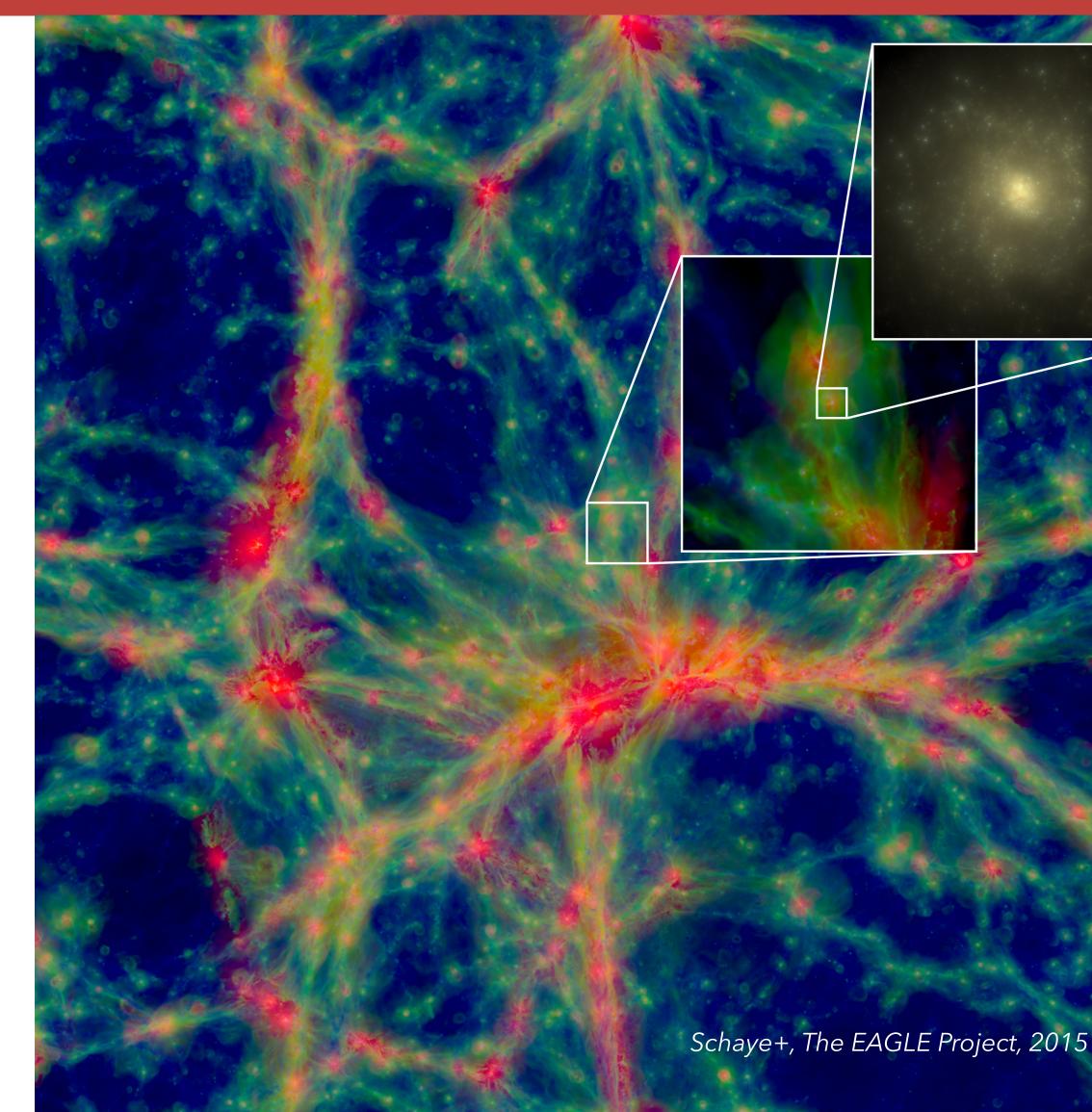


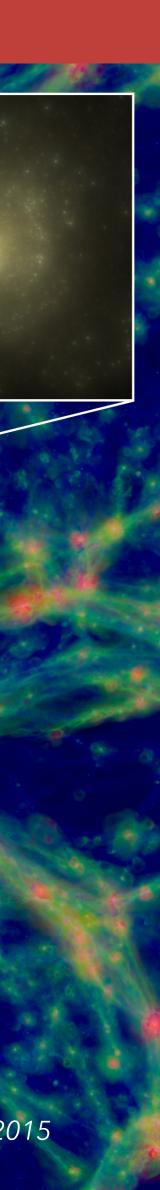
Frenk, N-Body Simulations of Galaxy Formation, Proceedings of the 130th Symposium of the International Astronomical Union, 1988



Present day state-of-the-art

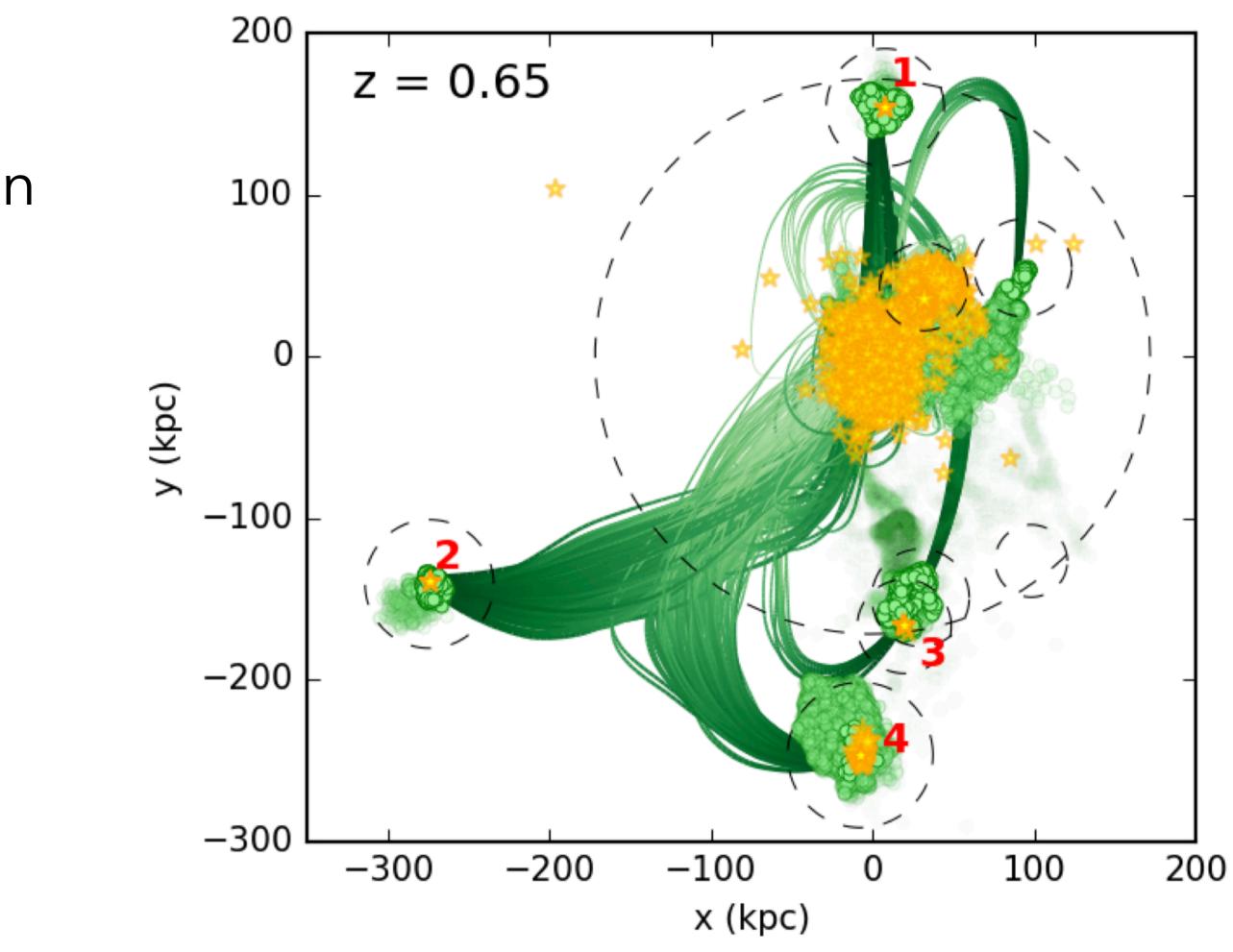
- Gas dynamics, feedback models, star formation...
- Forces are now repulsive as well as attractive
- Clearly all matter no longer follows the same, simple, gravitational path as before





Physical Motivation

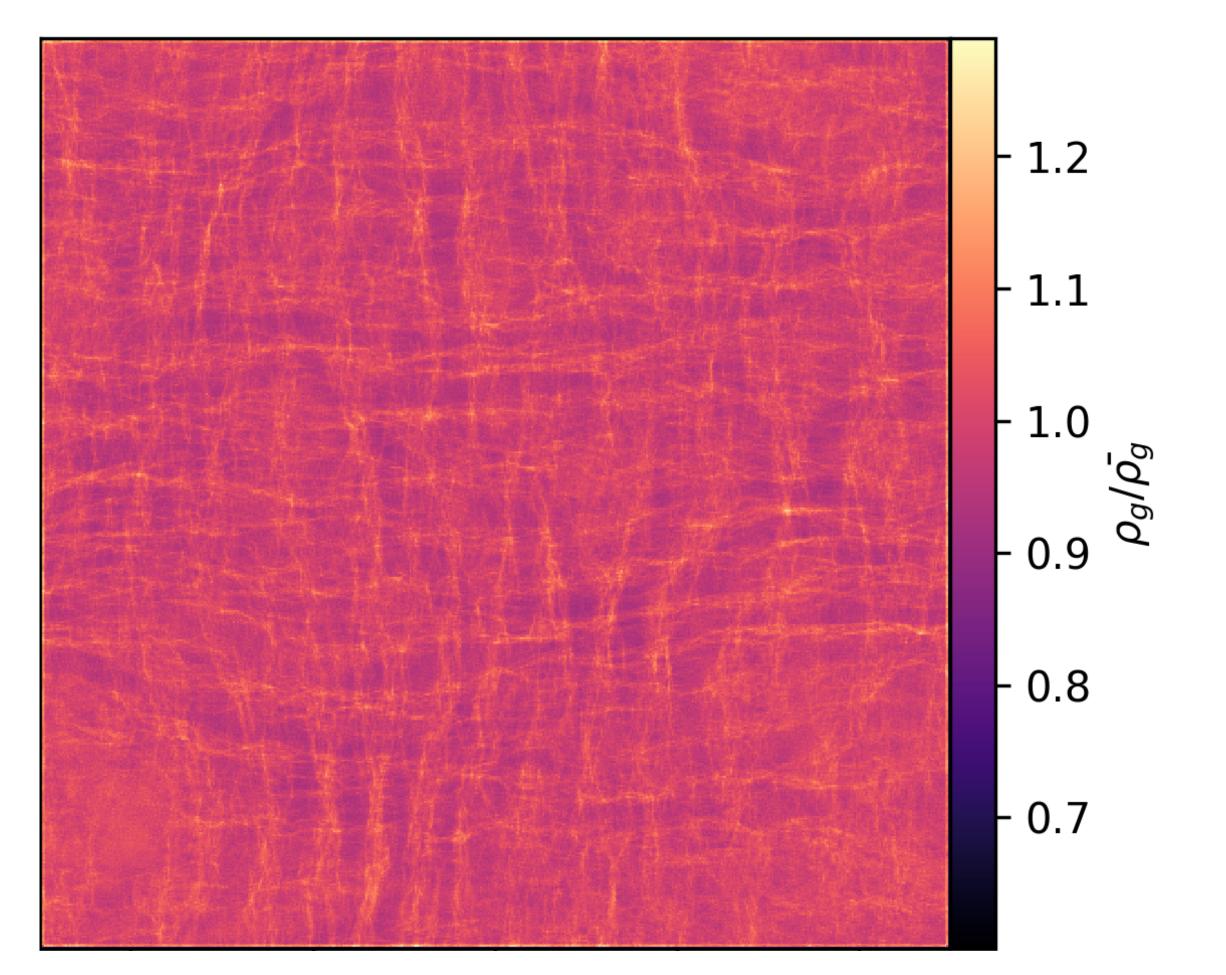
- Feedback causes gas to be blown out of galaxies
- This is especially true in simulations that include AGN feedback
- Where does that gas go?



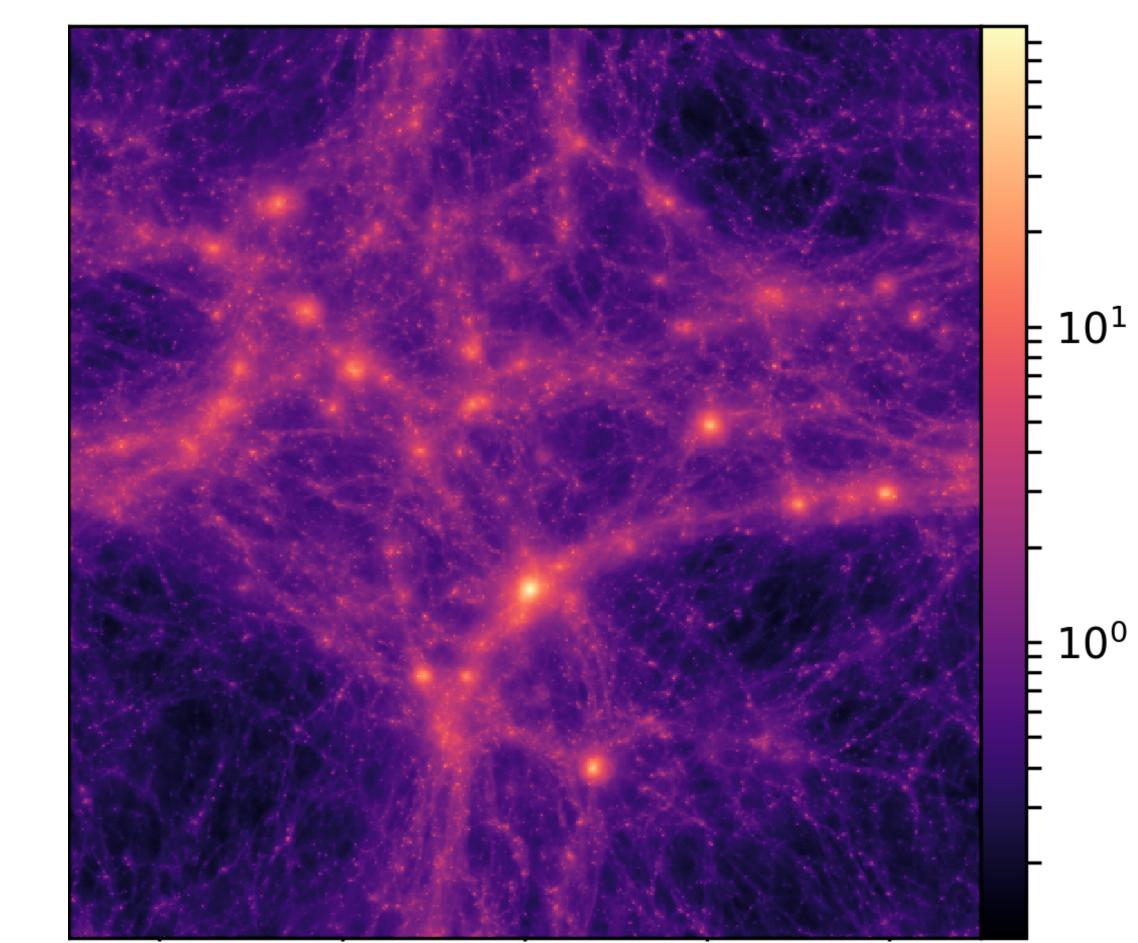
Angles-Alcazar+, Baryon Cycling and Galaxy Assembly on FIRE, 2017

Studying mass transfer

z=99





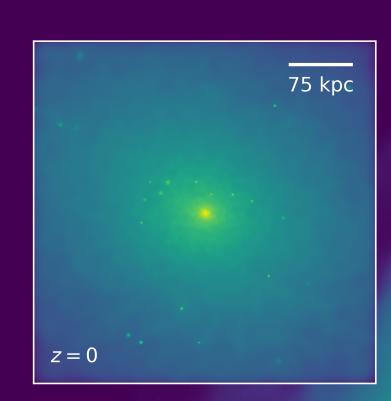




Identifying Lagrangian Regions

- Halos identified at z=0 by AHF
- Dark matter defines LR
- For each gas particle, find closest DM neighbour to find appropriate LR.

Lagrangian region for a high-mass halo in the Simba 50 Mpc box. Zoom-in shows the corresponding halo at z=0. Note the actual dark matter is uniform density.

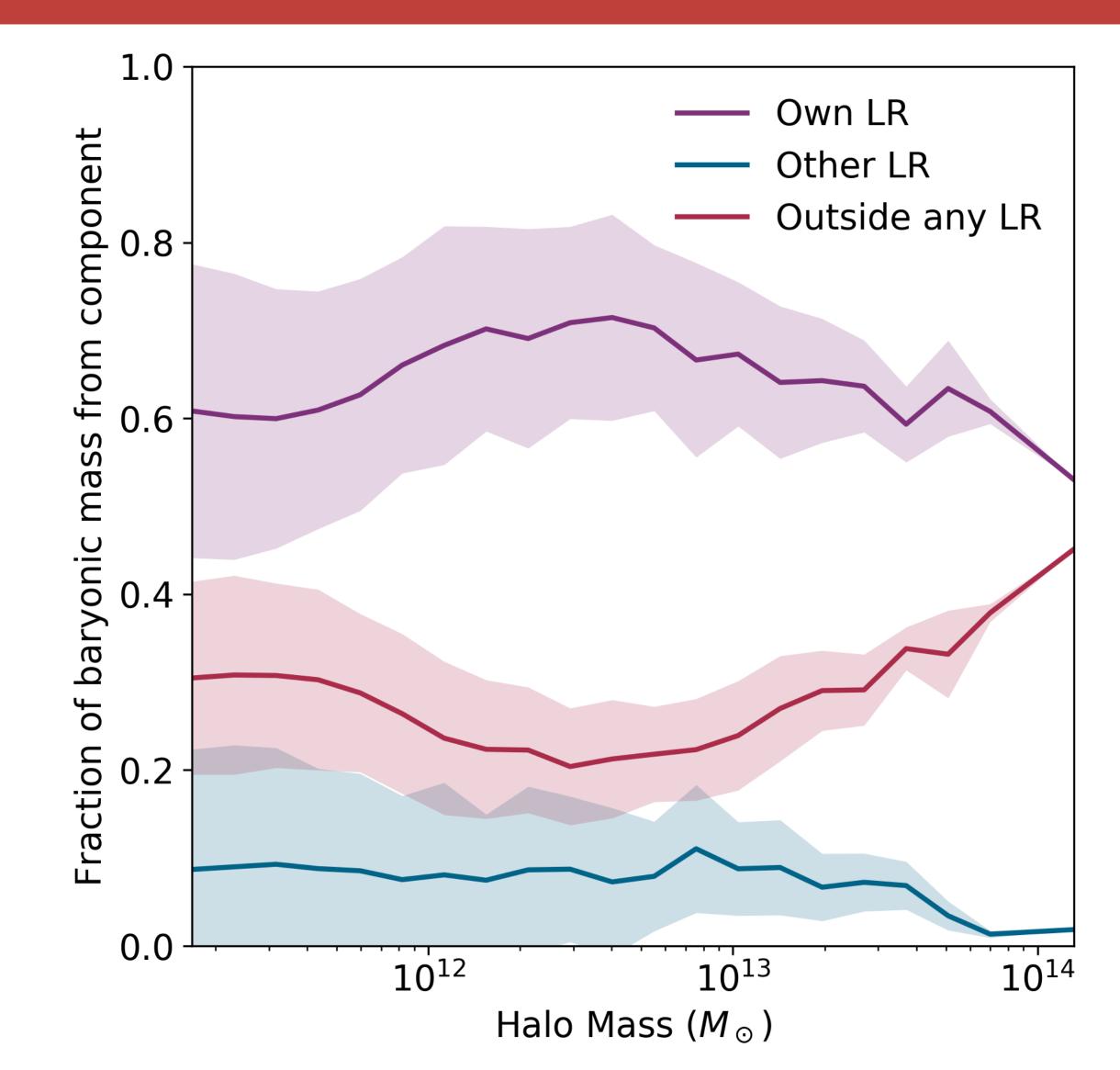


z = 99

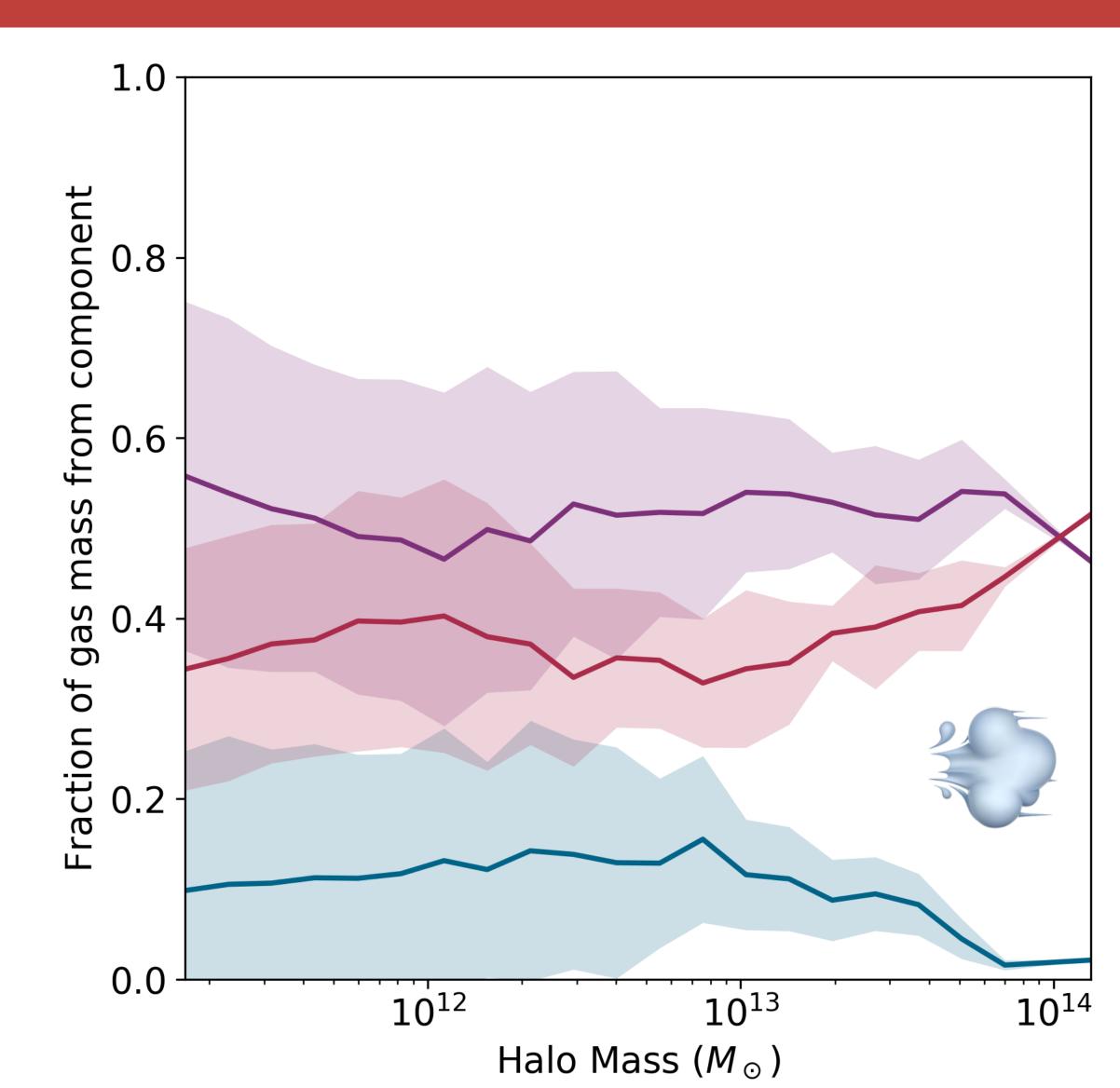


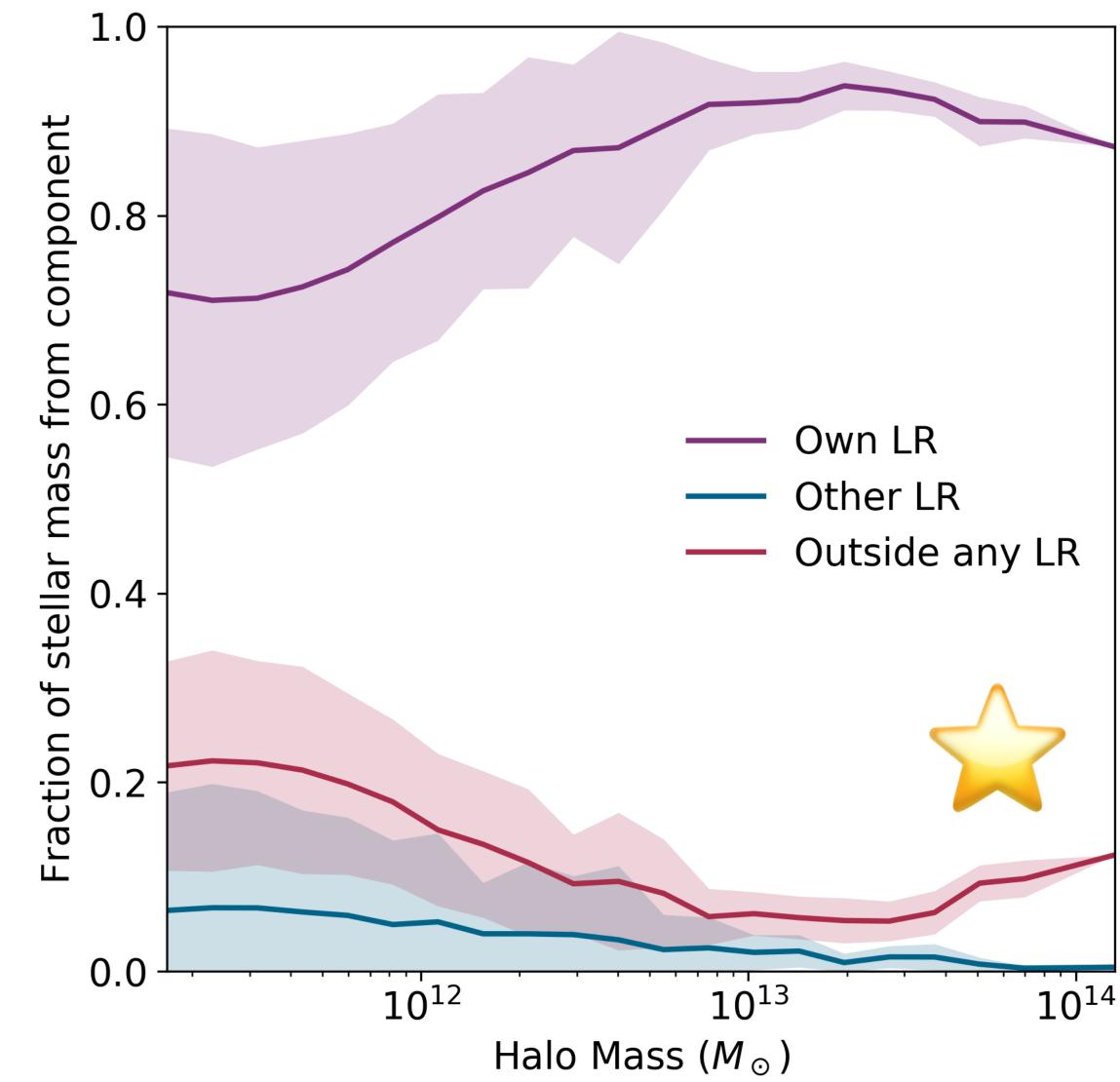
Computing transfer

- For every gas and star particle at z=0 we perform ID matching with the relevant z=99 progenitor.
- We then know the LR it belonged to, and the halo at z=0 that it resides in.



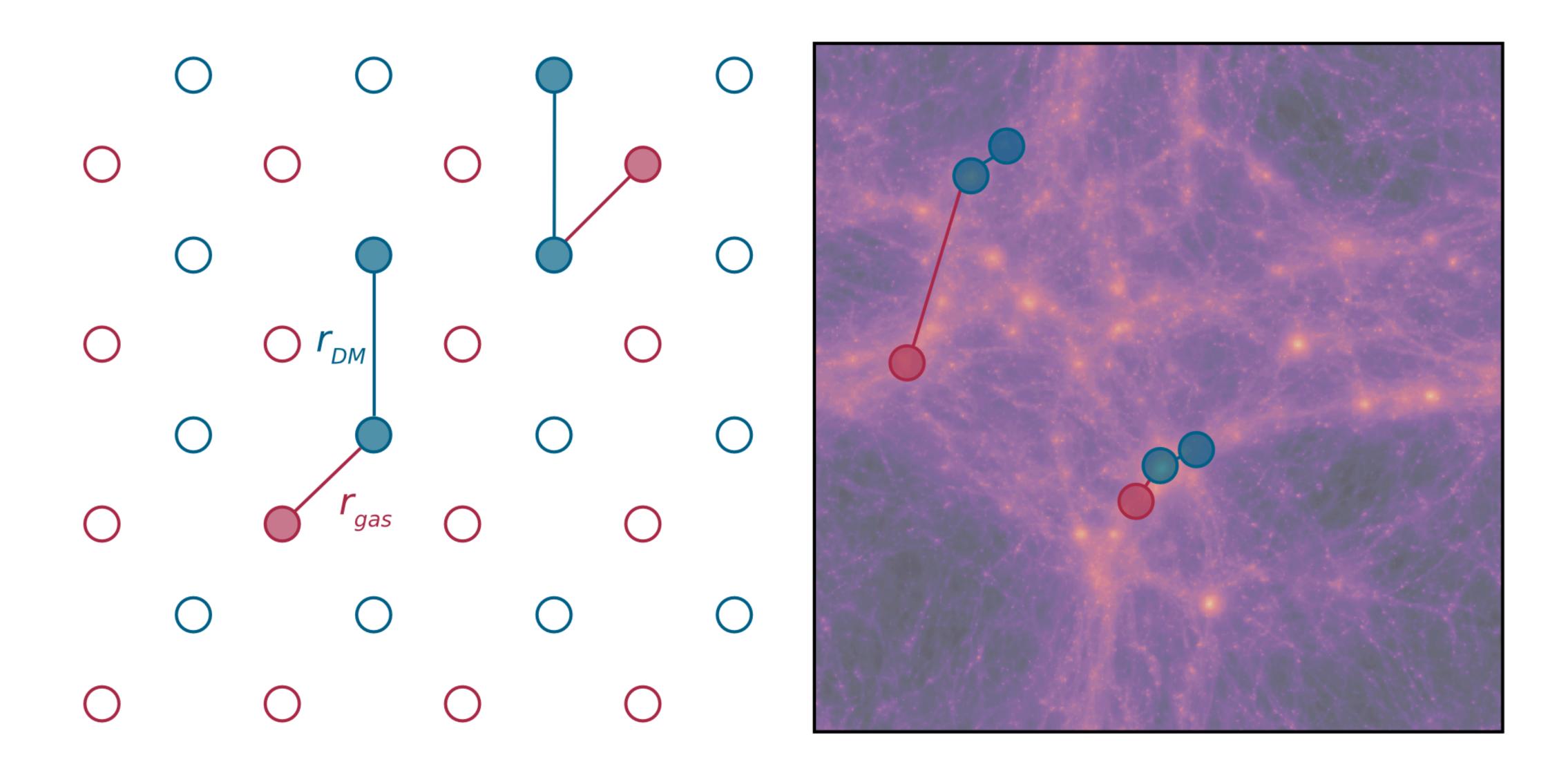
A closer look





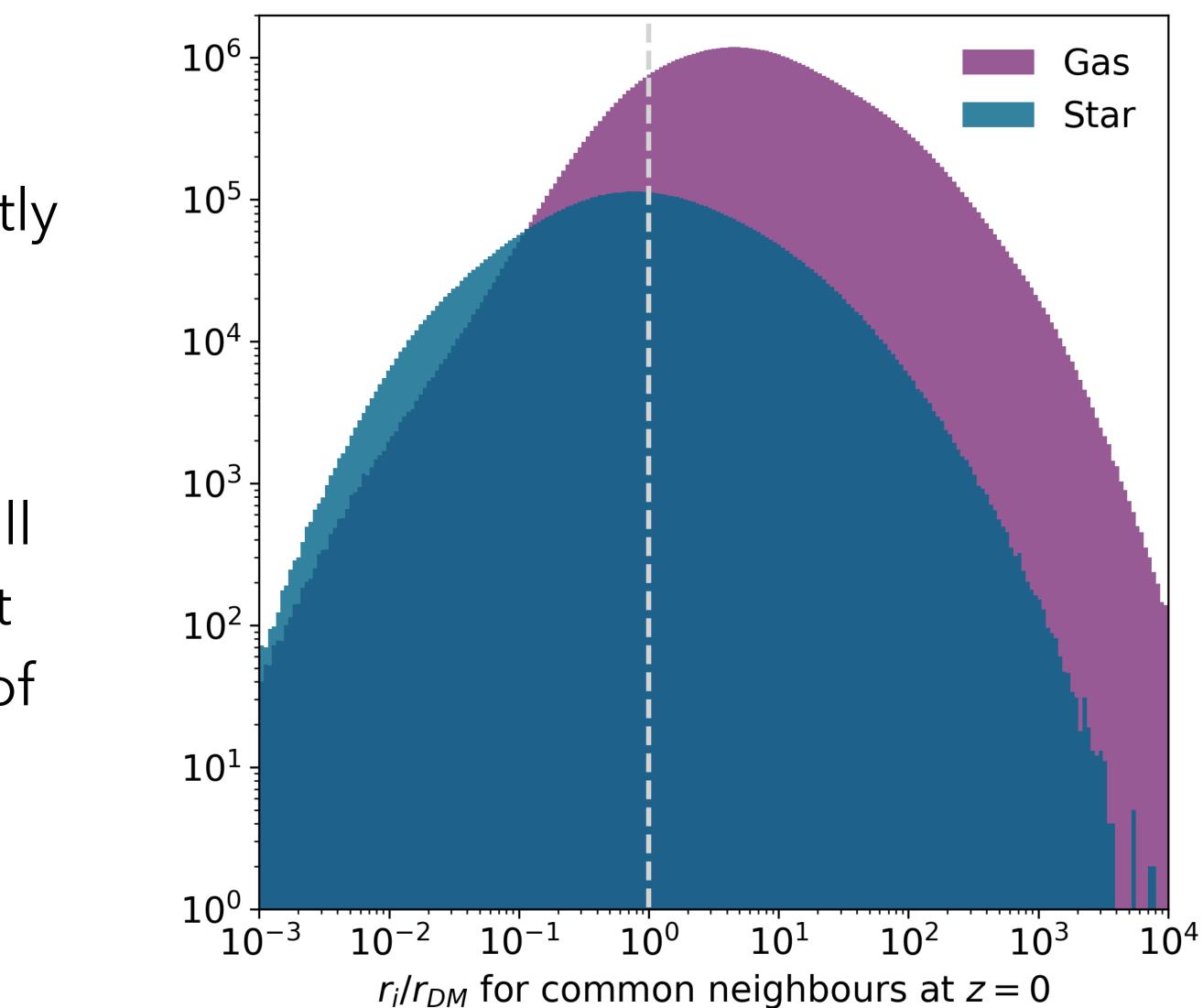


A halo-catalogue independent measure

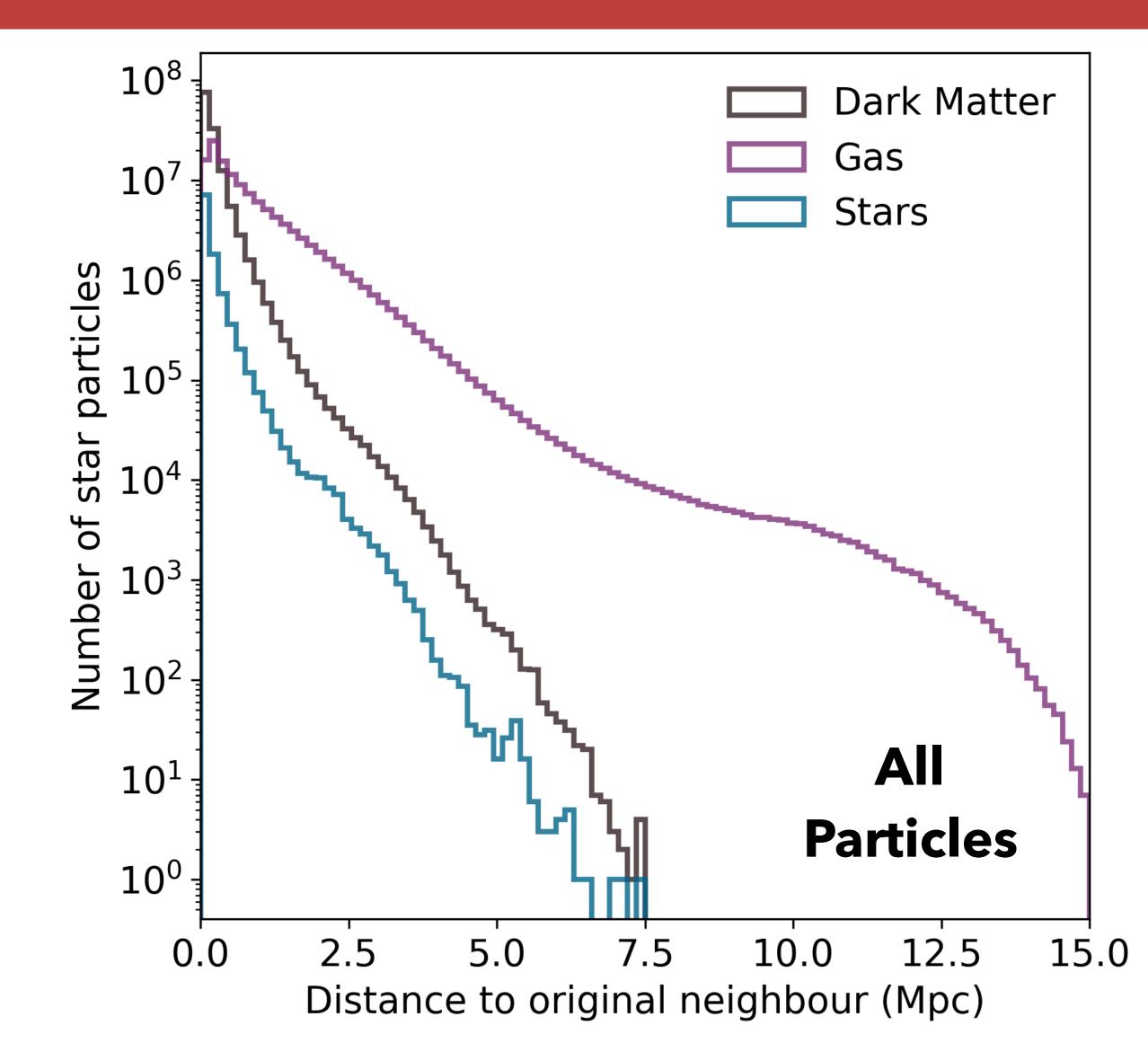


Who ends up further away?

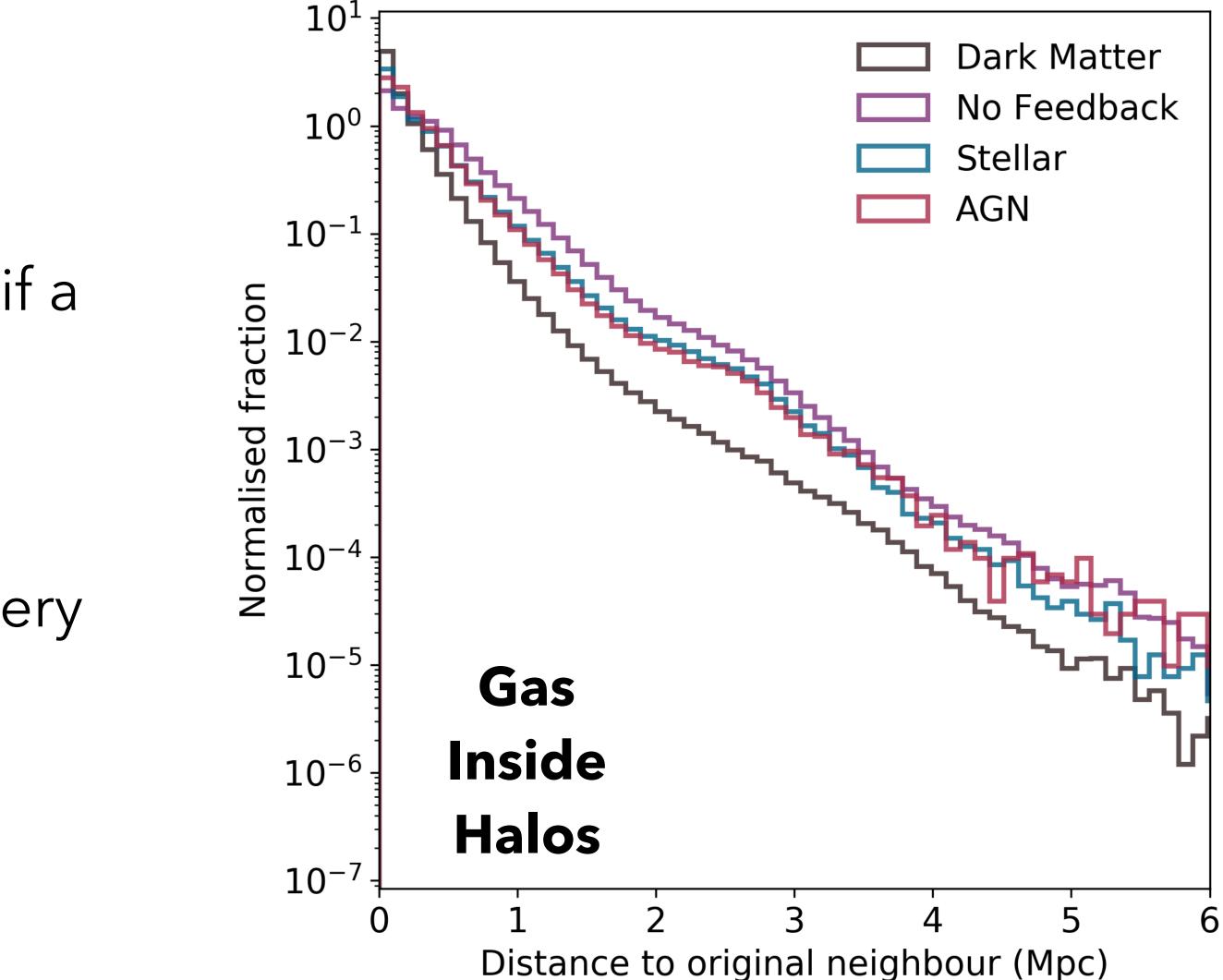
- Gas (and stars) end up significantly displaced from their original neighbour
- Gas dynamics either prevent infall (unlikely this is the major effect at z=0) or feedback blows gas out of galaxies!



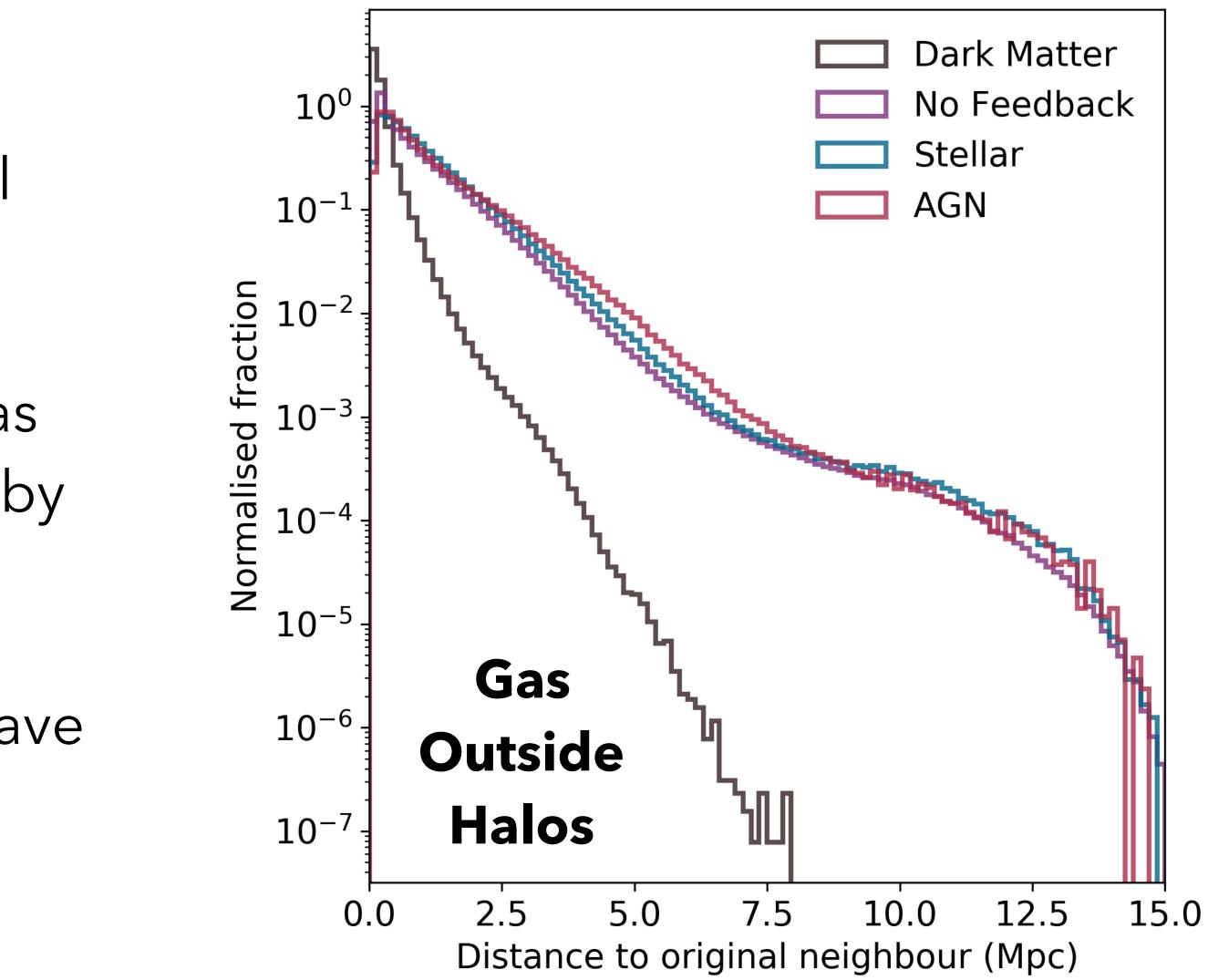
- Gas ends up with a much more extended distribution than the stars or dark matter
- Dark matter and stars end up with very similar distributions



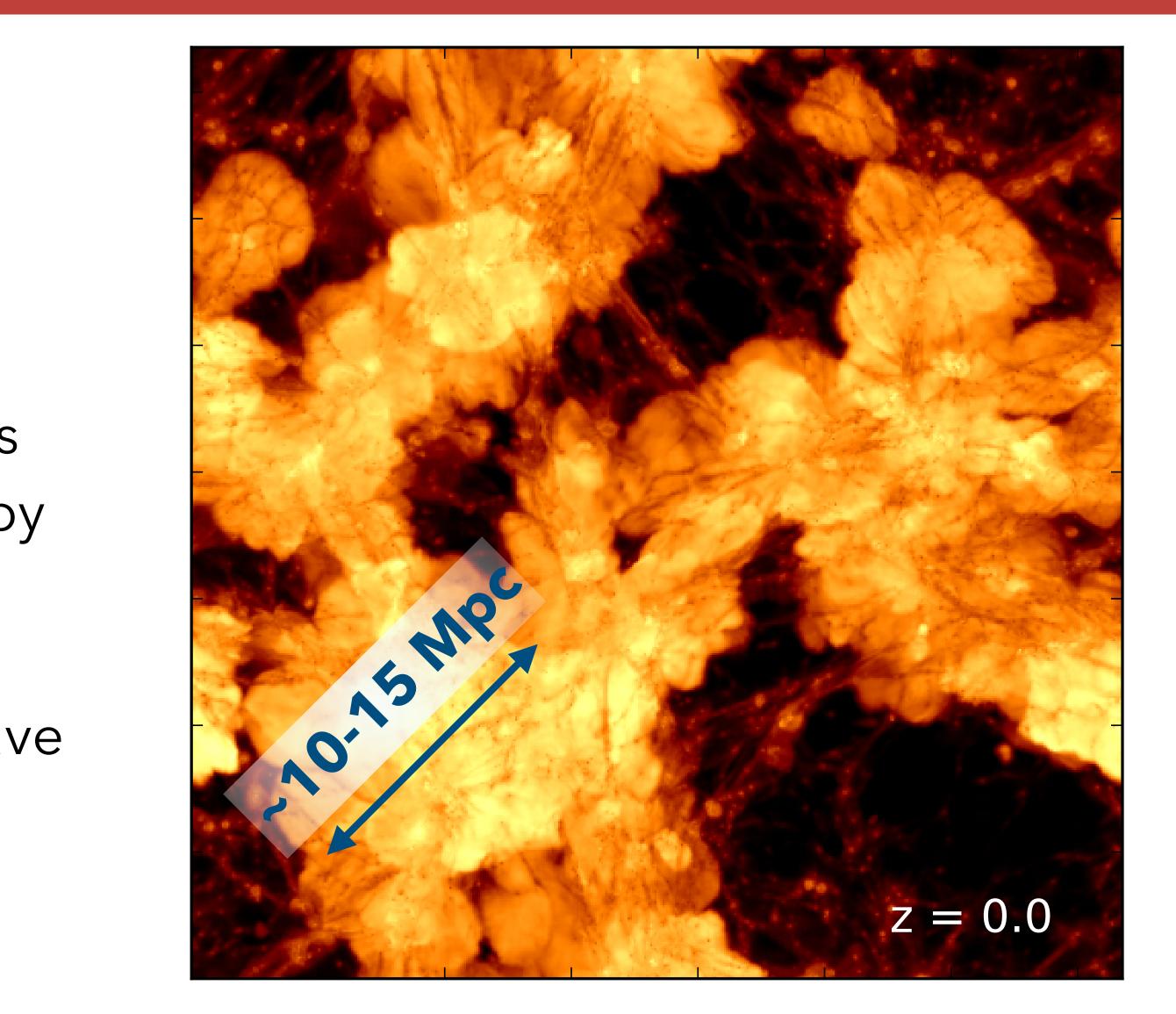
- Inside galaxies, it doesn't matter if a particle has interacted with a feedback process
- The gas and dark matter follow very similar distributions



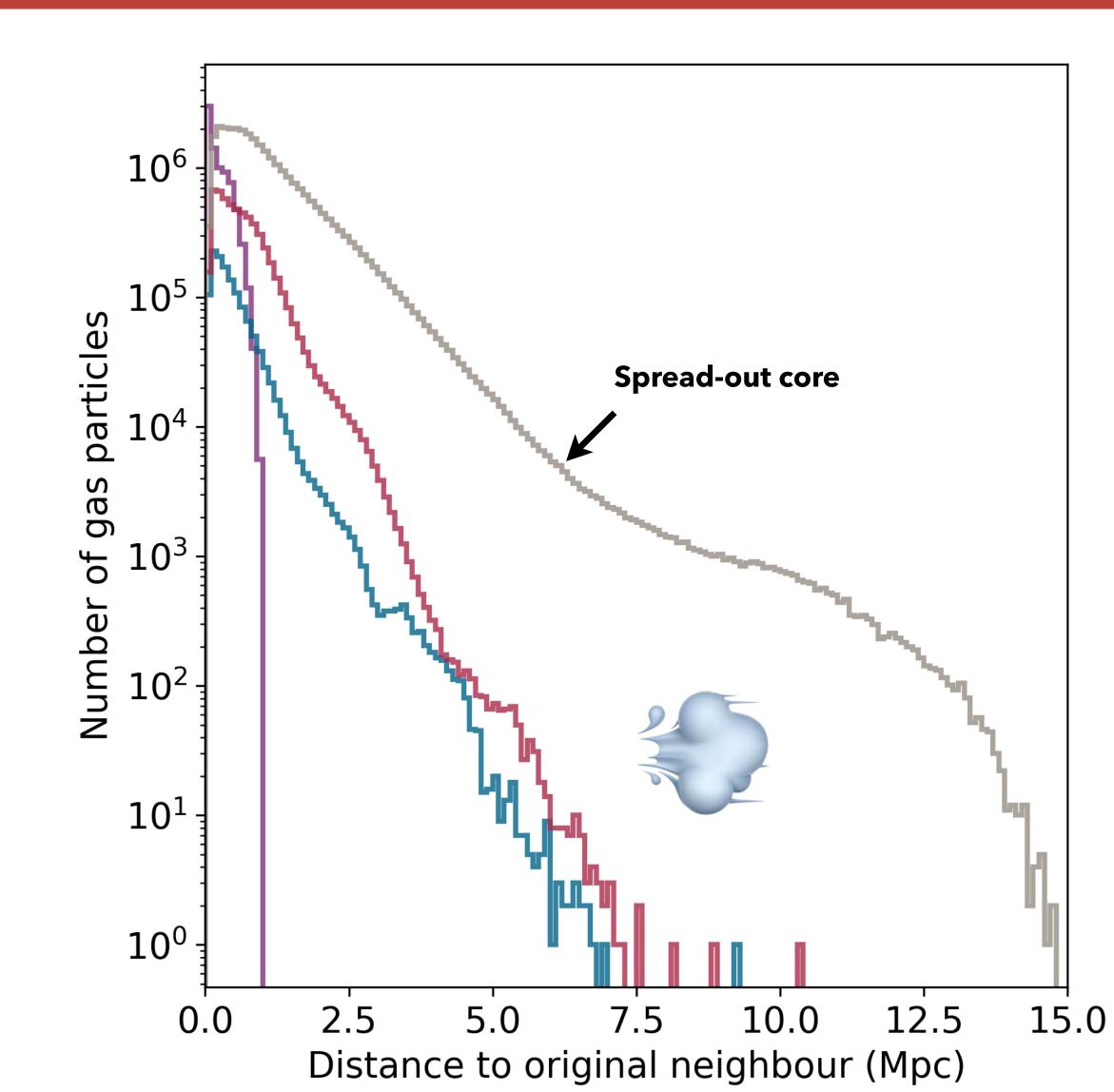
- Outside halos, we find particles blown out to many times the viral radius!
- This very long tail shows more gas that has been "touched" directly by AGN and SNe
- Note that other particles could have been dragged out and not be marked

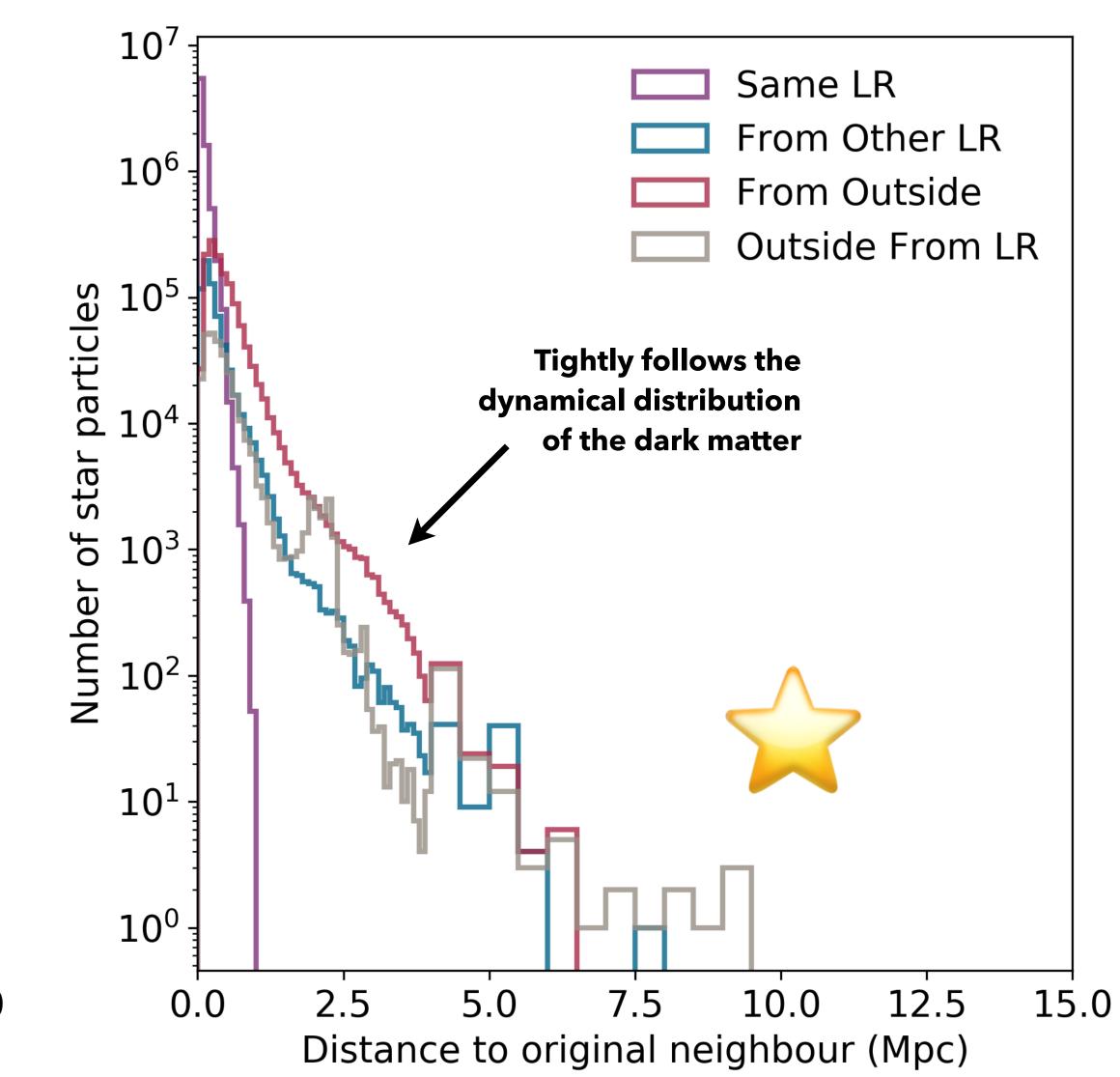


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Do stars and gas behave differently?







LTCaesar: Buy now!

- This analysis is completely general to particlebased codes
- Currently works with any gadget-oid
- Download the code and run your own analysis!
- https://github.com/jborrow/lagrangiantransfer
- Analysis is fast (less than 1 hour for 512³)

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Lagrangian Transfer

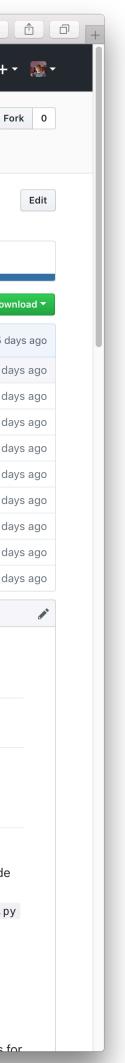
Josh Borrow, Daniel Angles-Alcazar, Romeel Dave

This small library is used to calculate the transfer of mass between lagrangian regions in cosmologcal simulations

Requirements

- python3 no attempts will be made to ensure that this code works with older versions of python
- in the analysis. The version of caesar that we recommend is the custom version available here: https://bitbucket.org/laskalam/caesar. You will need to run 2to3 on this, and then edit out references in the setup.py to the hg version. This is a bit of a pain at the moment, sorry.
- h5py for reading snapshots.
- numpy for numerical routines.
- scipy for the KDTree routines.
- tqdm (optional) for a status bar

And that's it! We assume that your output files are GADGET-oid compatible i.e. that they are HDE5 files with collections for



Ongoing questions

- What happens in a simulation ran without feedback?
- Is there a maximal scale for this transfer? (Need bigger boxes)
- What happens with different feedback models? Mufasa, EAGLE, ...
- Should this have an observational signature?

Conclusions

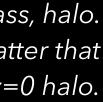
- Gas and dark matter end up significantly displaced from each other
- The particles that transfer can form stars; up to 10% of a given halo's stellar mass can come from other LRs
- Code available for download and use by the community.

• There is significant transfer between halos in cosmological simulations

On not using the convex hull

- The purple here is the LR of a single galaxy, with the white region being made up of the LR of another halo
- The holes/substructure in these LR's is not a problem, but a feature.

In white, the region where the gas comes from for a z=0, 10^{11} solar mass, halo. In red/purple, we see the Lagrangian region defined by the dark matter that will end up in the z=0 halo.



Caesar v.s. AHF

