The role of mergers in shaping a galaxy's stellar halo

The diffuse component of stars surrounding galaxies is thought to originate through the accretion disruption and stripping of smaller galaxies. The stellar halo provides a unique window on galaxy formation: it tracks the star formation histories of the smallest galaxies unobservable directly, as well the memory of the host's past merger history. Observations of stellar halos are undergoing a revolution: extragalactic stellar halos can now be targeted following enhanced capabilities in deep imaging (DRAGONFLY, GHOSTS, HSC and LSST or WFIRST in the future). The emerging consensus from these datasets is an unexpected diversity in stellar halo properties, with Milky-Way like galaxies showing both extended halos and non-detections. This diversity is thought to originate from the numerous possible mass accretion and merger histories for each galaxy. The goal of this project is to provide a clean test of this hypothesis using genetically modified cosmological numerical simulations. Genetic modifications can create different versions of the same galaxy, i.e. same dark matter halo mass and cosmological environment. Each version has a targeted change to its merger history, enabling controlled comparisons between scenarios. The aim is to systematically vary a galaxy's merger history and observe the response of its stellar halo.

Together with Tjitske Starkenburg and Lauren Anderson, I implemented a "particle-tagging" scheme during my visit at CCA. Particle-tagging is a semi-analytical approach, assuming that stars follow their dark matter counterpart in the stellar halo. Because it is based on dark-matter only simulations, it offers more flexibility and exploration capabilities than a full-scale galaxy formation simulation. The implemented scheme tracks all mergers and accretion events of a given dark matter halo, calculate stellar properties (mass, metallicity and age) of each merging body based on its halo mass at infall and paints the stars on the most bound dark matter particles. An application of this scheme to one of my existing high-resolution dark matter only simulation can be seen in Figure 1.

In addition to implementing the method, we clarified the key technical and scientific milestones for the future of this project. For example, we identified the required resolution of future dark matter simulations, the need to explore and test different models for semi-analytical star formation histories and the observable and analysis that could be readily done on simulation outputs. This process was extremely productive thanks to additional interactions with local experts (e.g. Robyn Sanderson, Lachlan Lancaster). We are now ready to start running genetically modified dark matter simulations and observe the resulting changes in stellar halos surface brightness profiles, stellar mass content or stellar kinematics. This will be the core of a first paper, as well as a building-block for proposals to re-simulate these objects with hydrodynamics and galaxy formation physics.

In addition to this specific project, I gave a lunch talk and shorter presentations at two group meetings. I presented the latest expansion to the genetic modification approach and discussed potential applications with local galaxy formation simulation experts (Tom Abel, Chris Hayward, Shy Genel, Daniel Angles-Alcazar, Tom Quinn and Alyson Brooks). We set-up concrete future projects and path of actions, which will result in publications on timescales extending beyond the end of my PhD.

This visit has therefore been instrumental, allowing me to make significant progress on a short-term project, constructing new collaborations for long-term projects. This work was supported by collaborative visits funded by the Cosmology and Astroparticle Student and Postdoc Exchange Network (CASPEN). I would like to thank the Flatiron Institute, and specifically Lauren Anderson and Tjitske Starkenburg, for their hospitality during the extent of my stay.

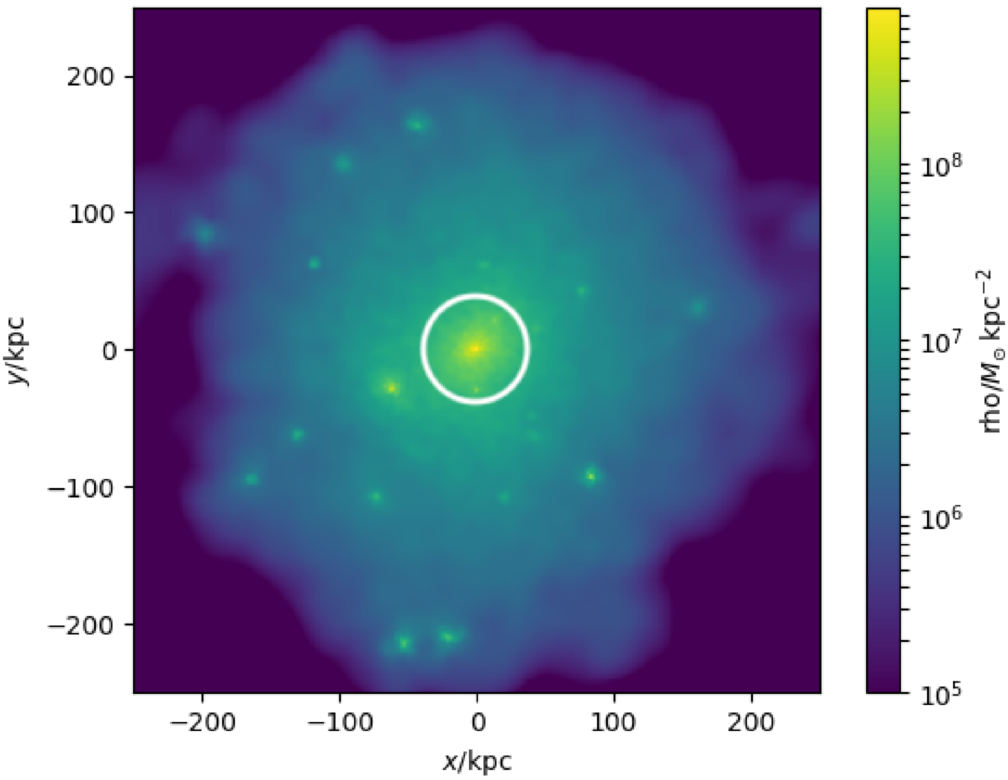

Figure 1: Projected map of stellar density in the stellar halo obtained with the implemented particle-tagging scheme. The method tracks all accretion and merger events in the history of a halo and paint stars at first infall based on a semi-analytical recipe. A white circle of radius 30 kpc highlights the typical size of the inner region of the halo, unresolved by this approach neglecting the effect of the central galaxy. This method is a key step towards generating dark matter halos with genetically modified merger histories and observing the resulting changes in stellar halo properties.