1 Purpose:

We run a SAM on high-resolution merger trees of MW sized halos to understand the star formation histories of MW satellite galaxies. Because we need to keep a high enough mass resolution to resolve details in the histories and to archive numerical convergence, the computation can be time consuming. The computation demand becomes a more difficult issue when we need to imbed each SAM run as one likelihood evaluation in the computation of parameter space exploration. We need to find a computation scheme where we can significantly reduce the computation time for simulating the star formation histories of MW galaxies while maintaining the accuracy of the simulation.

2 The scheme:

We propose a scheme of utilizing high-resolution merger trees for SAM calculation of simulating existing satellite galaxies. We notice that most of the MW halo progenitors do not survive as a sub halo existing at the present day. Therefore, spending computation on those branches of the merger tree that do not counterpart a existing satellite galaxy does not produce useful results for our study. In the scheme, we identify existing sub halos which are possible to host a satellite galaxy of our interests, and track only those sub halo merger tree branches for the SAM calculation. When we follow the sub halo merger trees, we still keep track if any progenitor of the sub halo is a sub halo of any halo or a distinct halo, and apply appropriate treatments to simulating galaxy formation in the halos. At the same time, we also follow the main-branch of the MW main halo. By doing this, we predict the properties of the central galaxy, the MW, as by-products. Other than the main-branch, we ignore all other branches of the merger tree of the main halo in the scheme.

3 Numerical behavior:

We use a set of high-res N-body simulation merger trees to test the numerical behavior of the proposed scheme. The tests show that the scheme can save a significant amount of computation time and maintain fairly good accuracy for the SAM predictions.

1). Computation time: The merger trees have a mass resolution ~5x10^5Msun. A significantly number of halos in a MW sized halo are progenitors that are disrupted by the final time. Typically, there are 1-2 million halos in a merger tree of a MW halo, but more than half million halos do not remain as a resolved sub halo at z=0. For example, in Halo_0606, there are 1,390,496 halos in the tree, and 730,894 of them are halos do not survive at z=0. A rough estimate tells us that following our scheme can save about half of the computation time. We run the SAM on the merger trees. The actual calculations prove the estimate. As an example, for Halo_0606, the full computation for the entire tree is 14.076s, and the new scheme reduces the time to 6.239s.

2). Accuracy: The scheme achieves fairly good accuracy in reproducing the stellar mass of satellite galaxies. We take all satellite galaxies with host sub halo mass > 10^10Msun at z=0 predicted by the full SAM and the same one predicted by the new scheme. The following figures show two example halos. There are 1294 and 2016 sub halo satellites in each halo satisfying the criterion. Each red dot in the left panel denotes a satellite. The a-axis represents the final stellar mass as predicted by the old (full) treatment, and y-axis represents the relative difference between the two calculations, (M_new-M_old)/M_old. The stellar masses of the majority of the satellites are accurately recovered. Only a few outlines exist. The blue hexagon denotes the central galaxy (the WM). The error in the stellar mass of the central is about 10%. The right panel shows the histograms of the error distribution for the satellites. More than 95% of the satellites are predicted with identical stellar mass.

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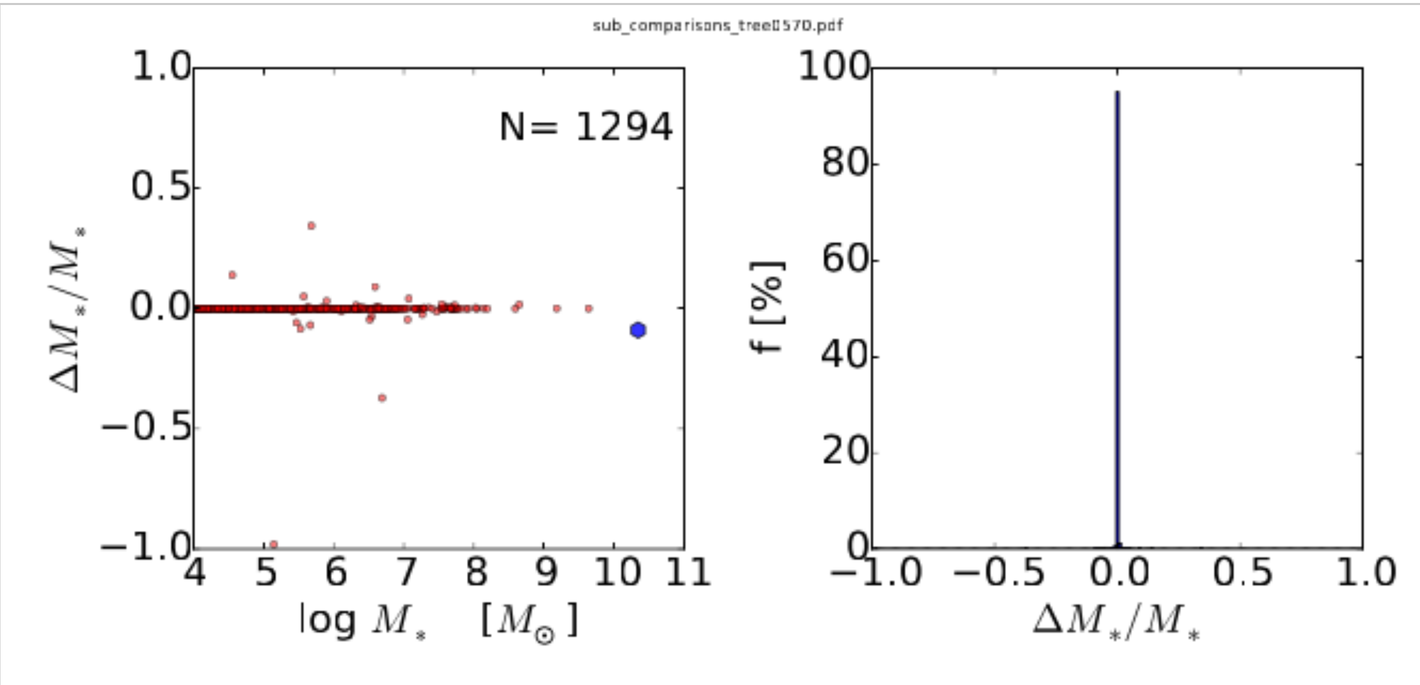

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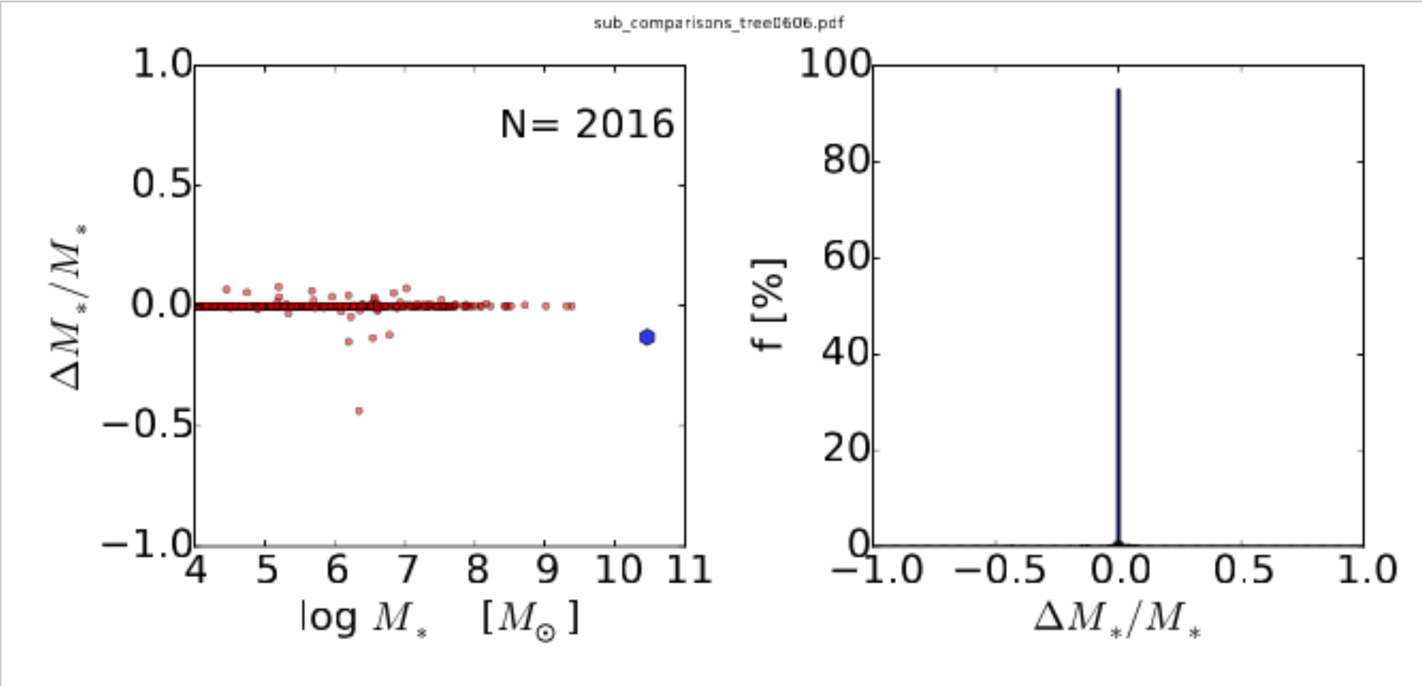

4 Reason of the discrepancy:

4.1) Environment history of sub halos:
We show a sub halo merger tree in the figure below. Only progenitor halos with mass > 10^8msun of the sub halo are plotted. The x-axis is the x-coordinate of the halo relative to the main branch halo center. The y-axis is from high-z to the present-day from bottom to top. Different color indicates the environment of the progenitor. We use red to denote the halo when it is a distinct halo, and all other colors to denote when it is a sub halo. Green indicates that the halo is a sub halo of the main-branch halo of the final MW. Blue indicates that the halo is a sub halo of any other progenitor halos of the main MW halo. Cyan indicates that the halo is a sub halo of any branch that end up with an existing sub halo at z=0.

We find that many sub halos going back and forth to be a sub halo of the main branch and a distinct halo (green and red segments) at late times. Also, a lot of them was a sub halo of the other branch of the main halo merger tree (blue).

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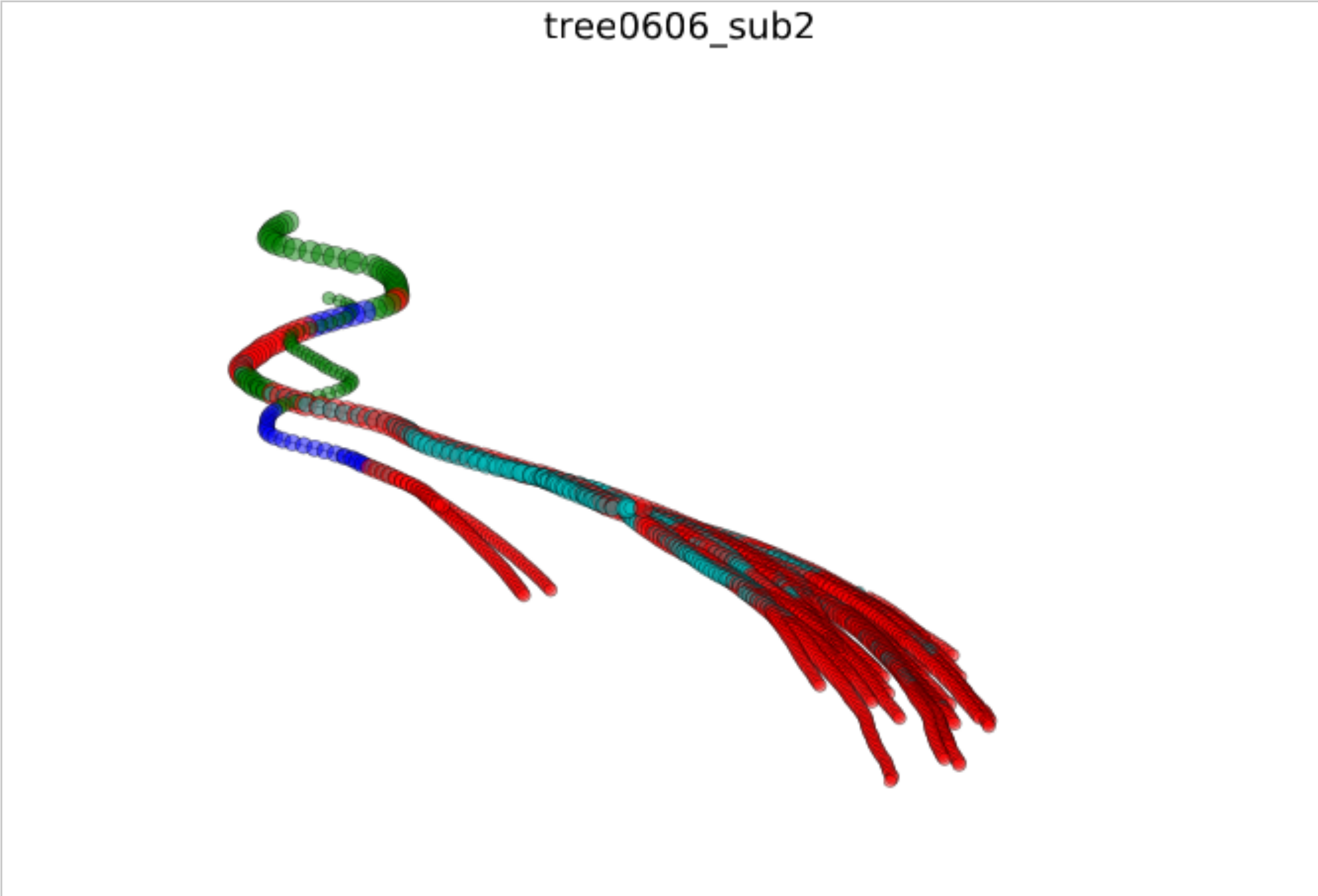

We select the sub halos that have an error in the final stellar mass larger than 10% and plot the history of those halos down to the mass resolution limit (5x10^5\msun). They all of have period of time when they are sub halo of a non-main branch progenitor (blue).

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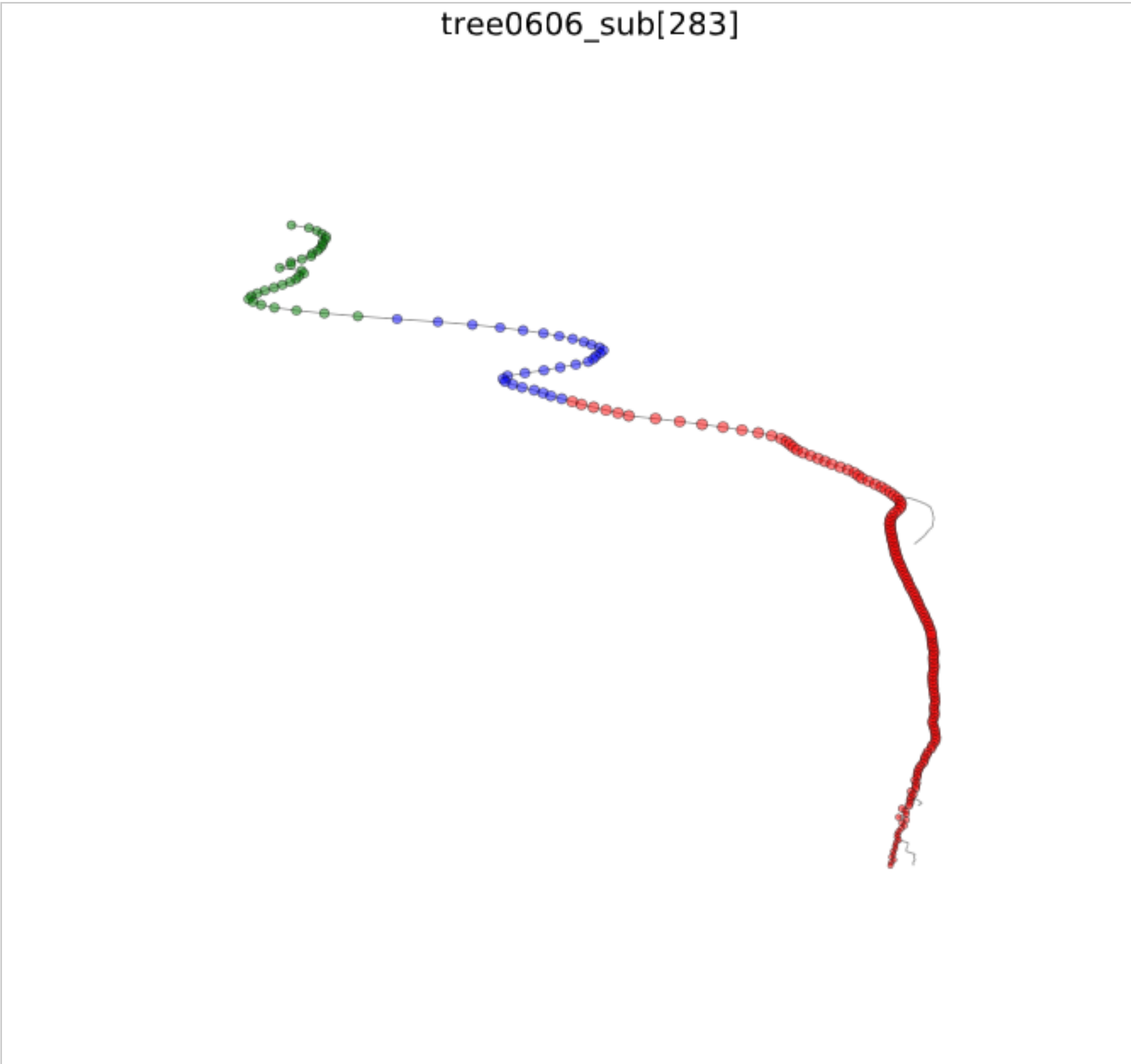

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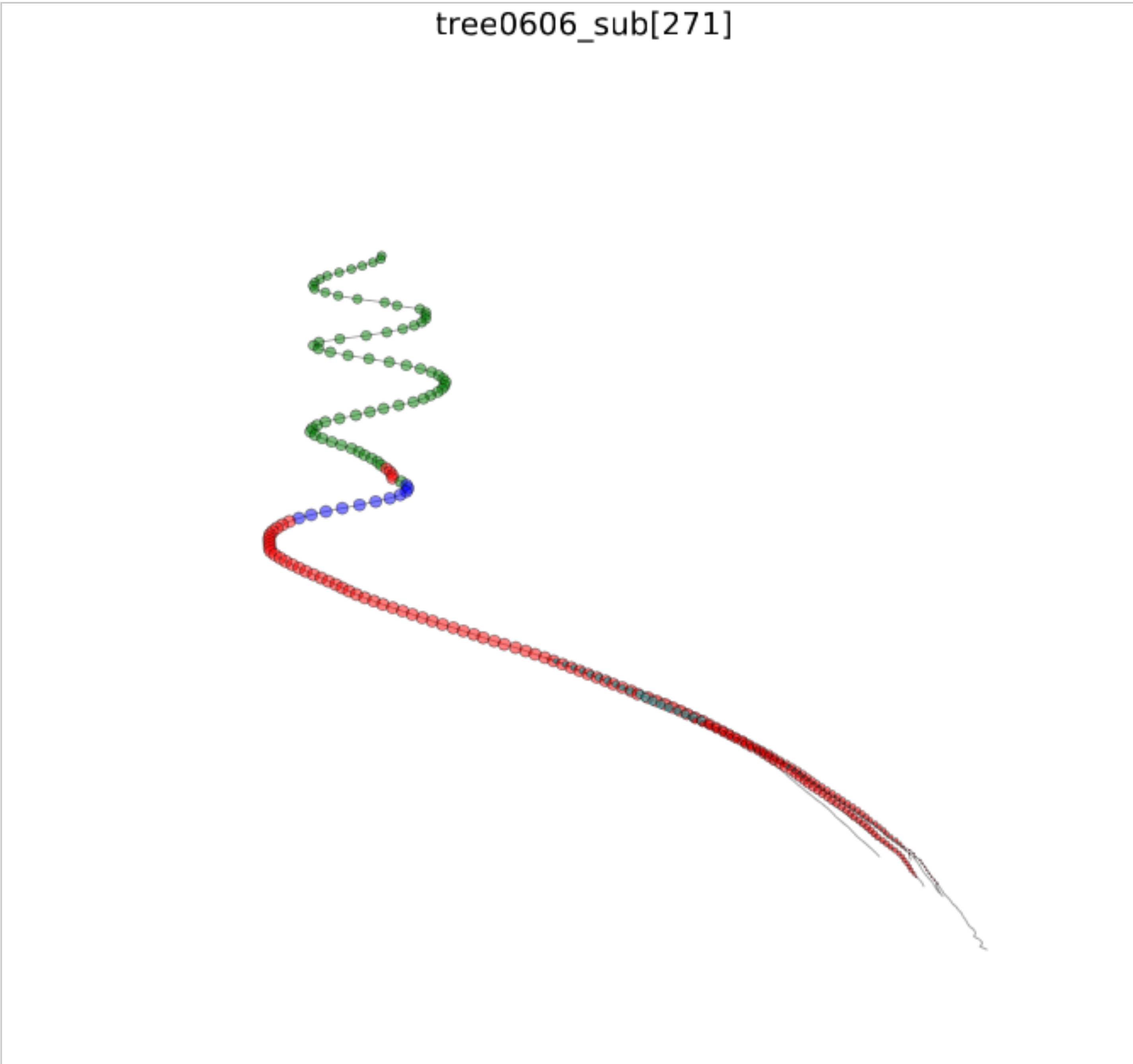

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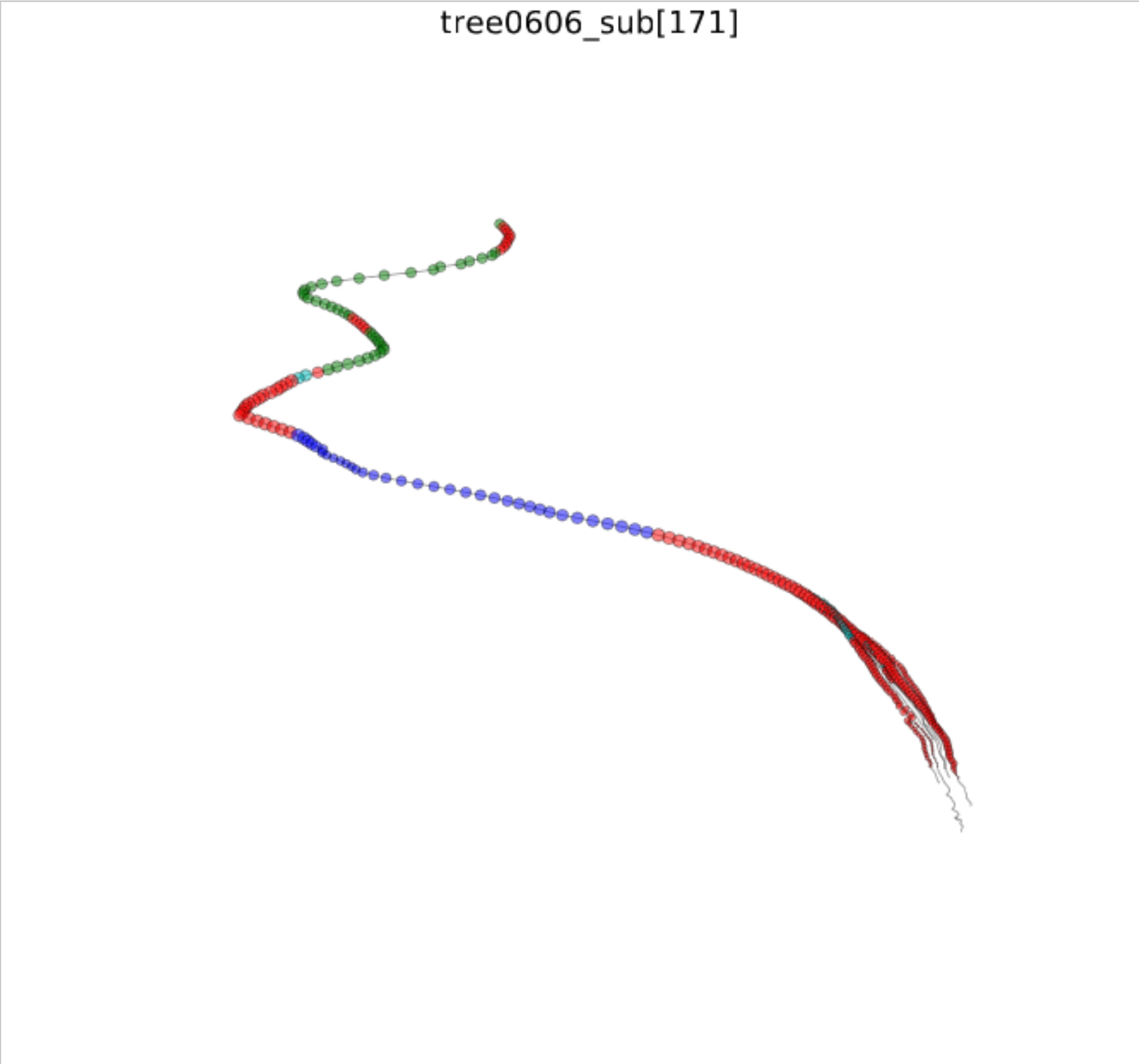

However, we find that being a sub halo of a non-main-branch progenitor does not always cause an error. Examples are shown below.

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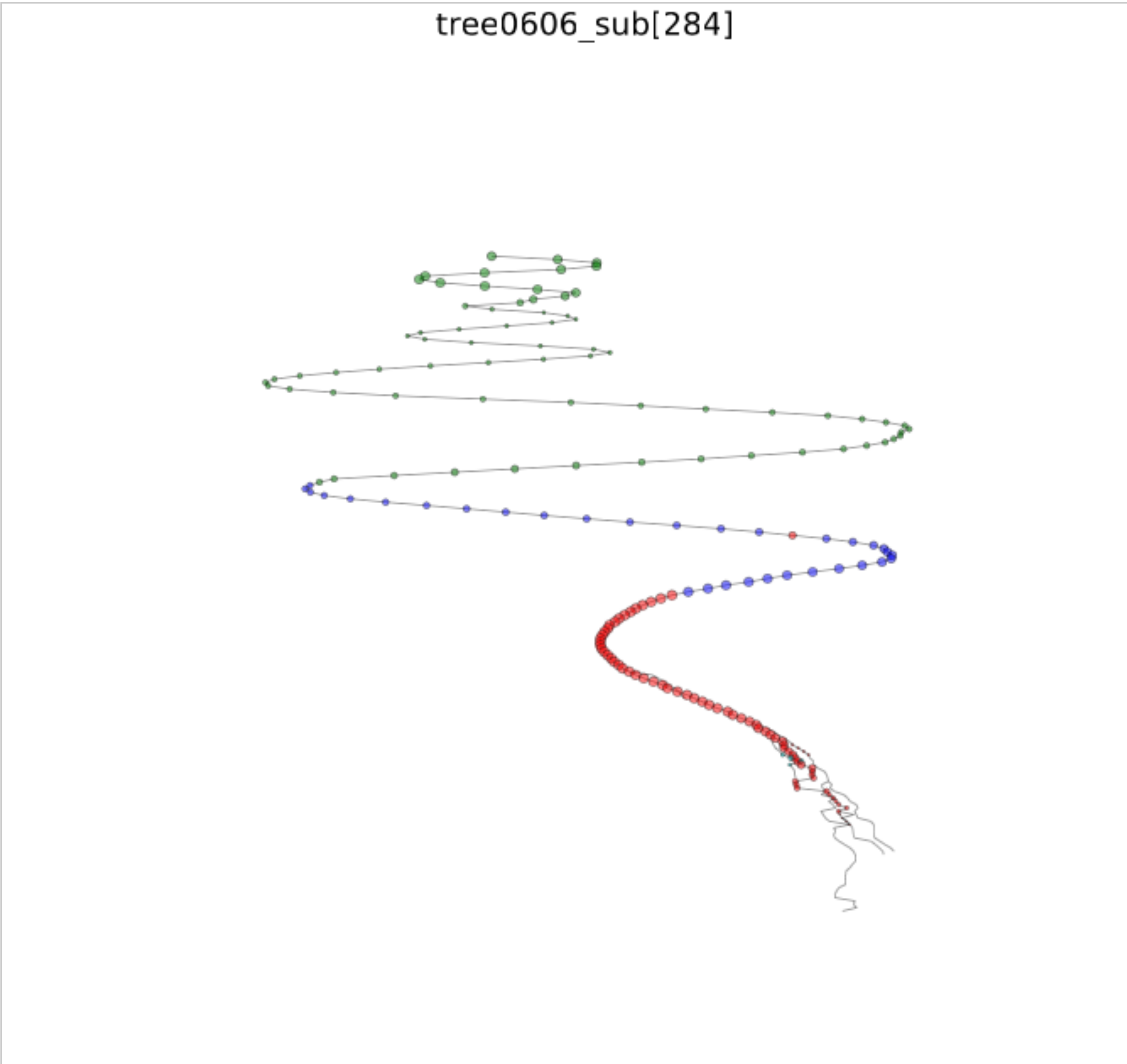

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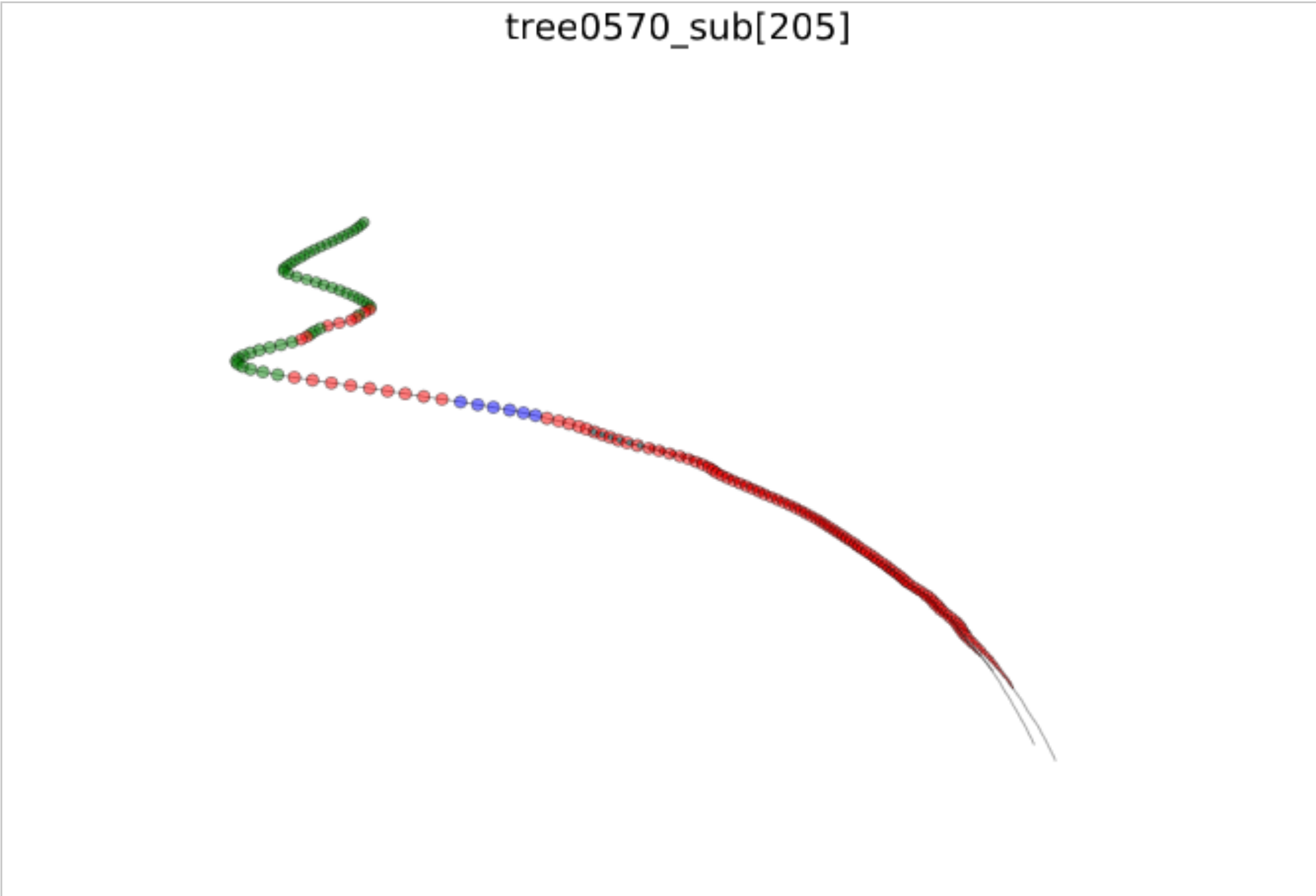

4.2) History of hosting other halos:
We find that the reason for the discrepancy is that when a sub halo ever hosts a sub halo that is ignored in the new scheme when it was a distinct halo, the total hot baryon mass of the halo is different. When this happens, it make some discrepancy in the final galaxy mass. We show some examples. Sub 204 and 645 are subject to the discrepancy. One can find those halos have a segment of merger history with magenta color, which indicates the halo is hosting a sub halo that is ignored. Sub 205 and 646 have exactly same predicted galaxy mass with the new and old scheme. They either do not have a magenta segment in the entire history, or have a magenta part that is at the time the halo is already a sub halo (green).

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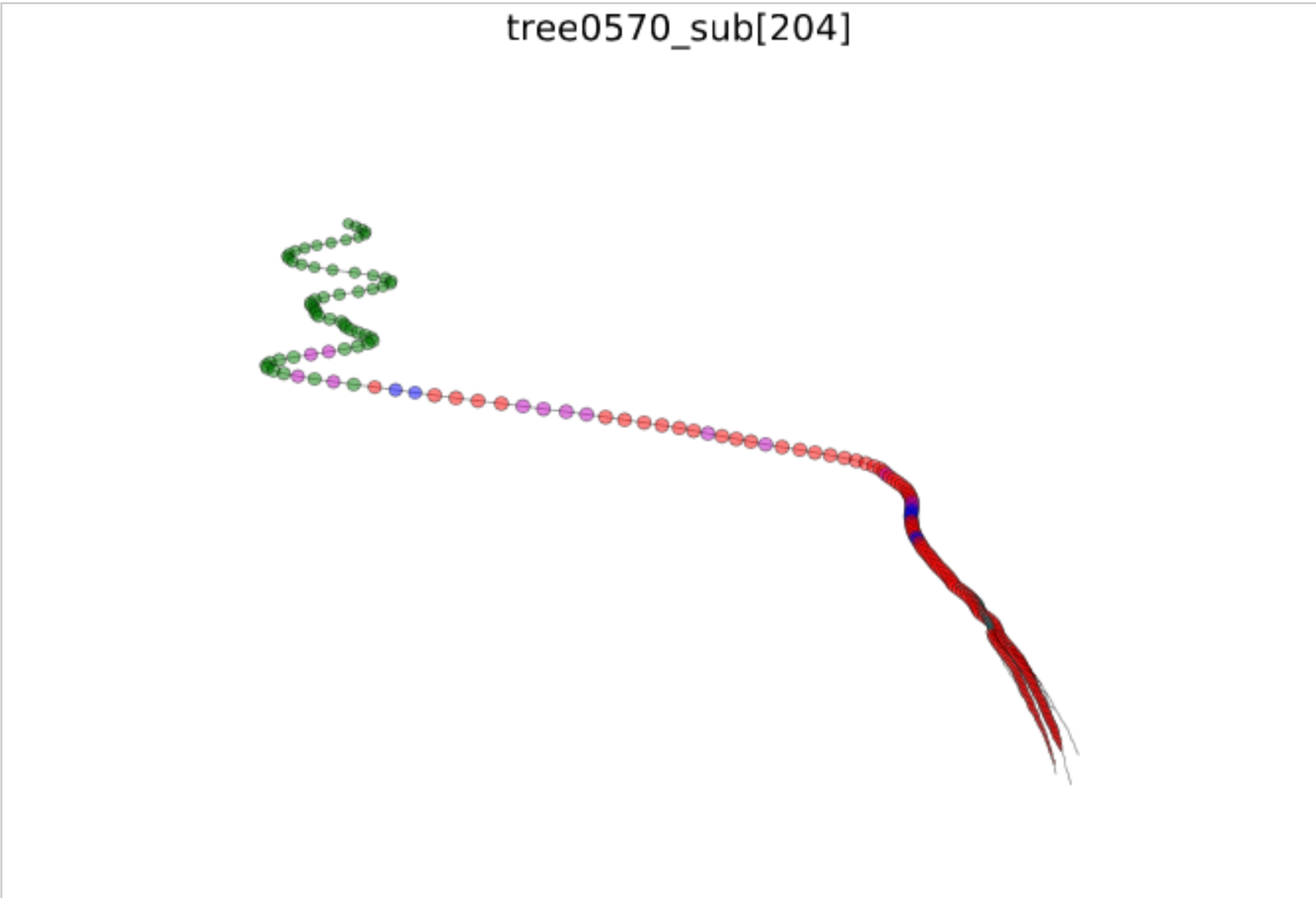

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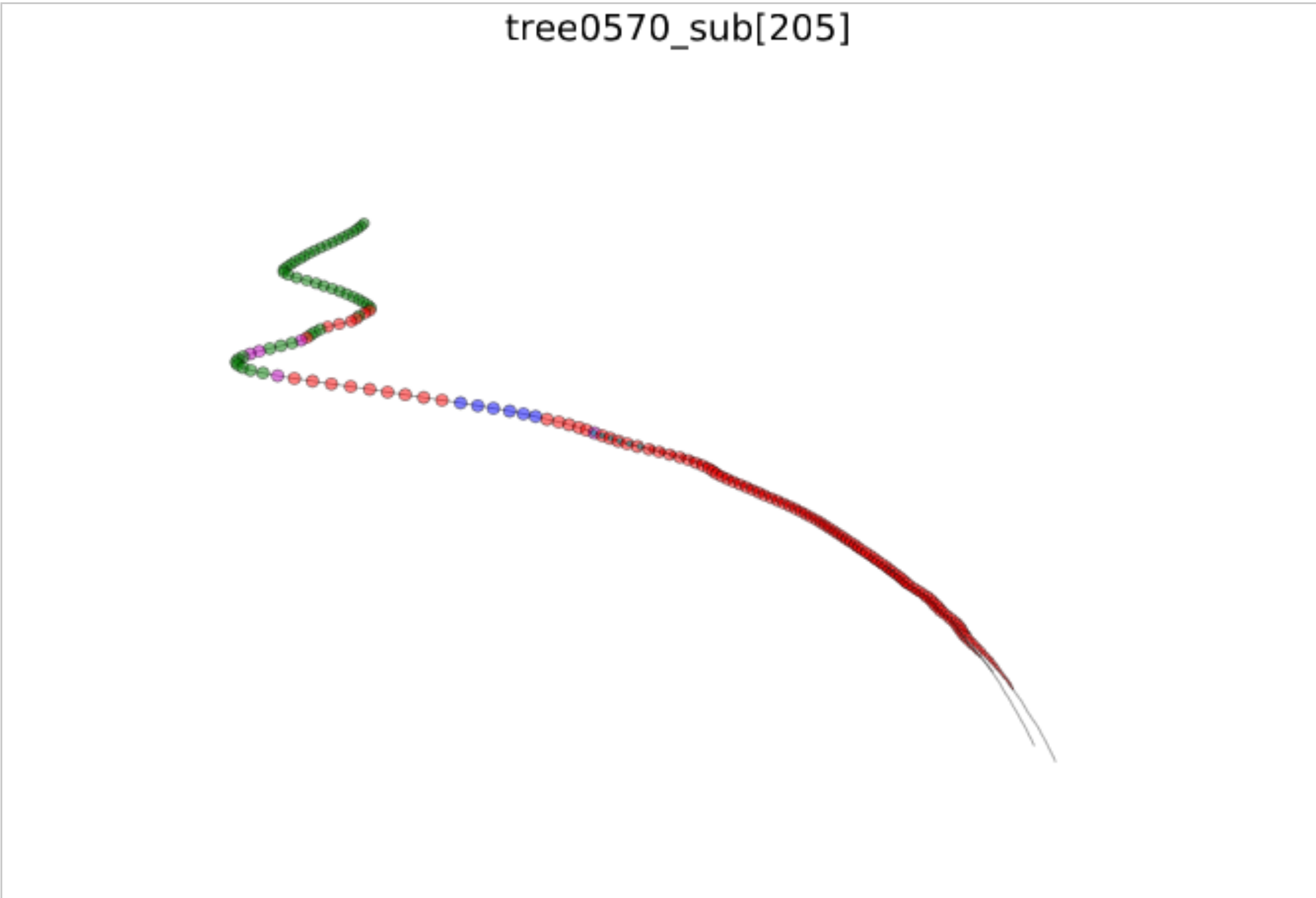

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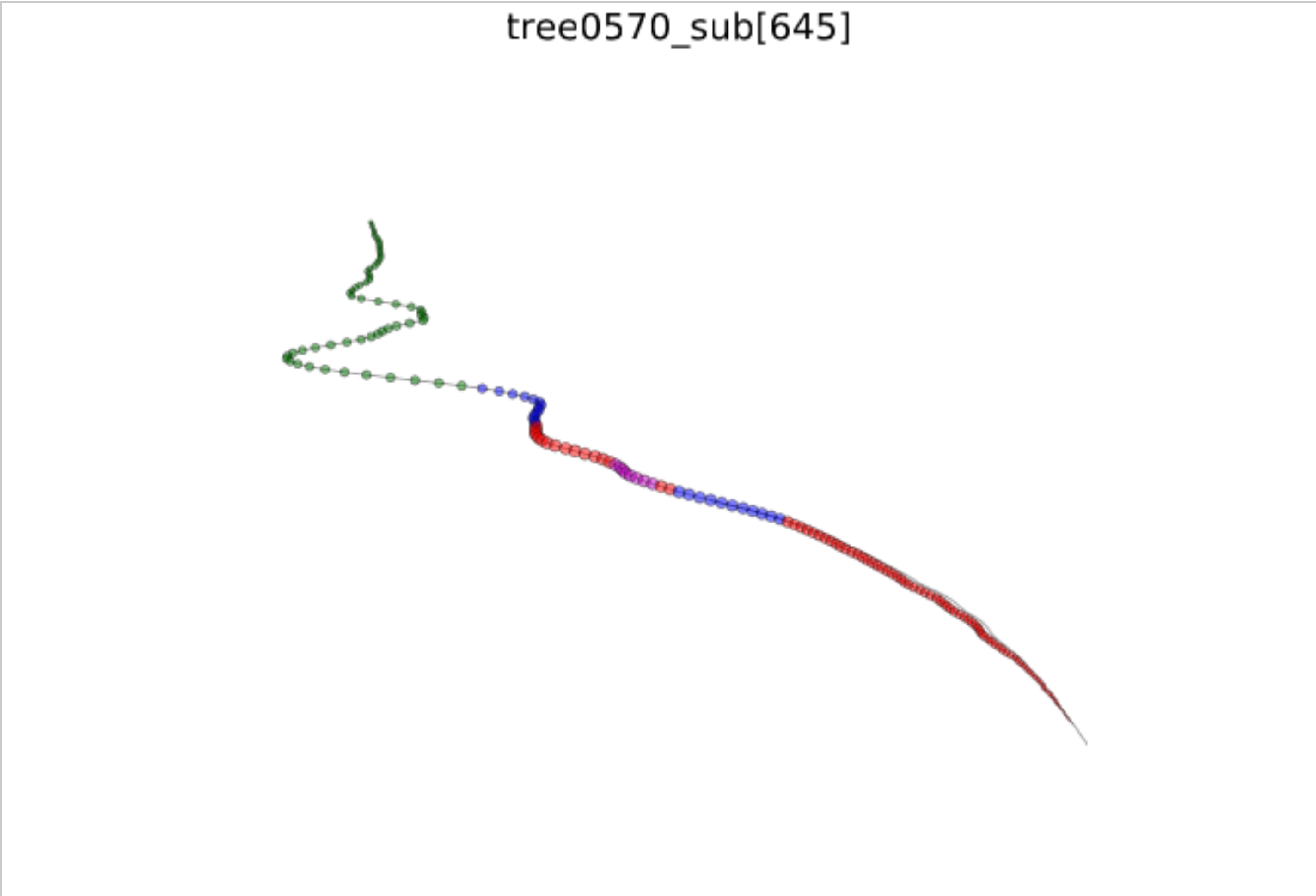

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