PRELIMINARY WORK WITH ILLUSTRIS-3 (Z=0)

April 20, 2020

Nikhil P. S. Bisht
Max Planck Institute of Astronomy

Contents

0.1 Introduction

I redid the exercises with the inputs provided and instead of processing many things like mass of various entities like Stars, DM, etc on my own from the snapshot, I used the Halocatalog which had pre-processed values.
I also understood the difference in how the different subhalos, etc are categorised by the FoF (Friends of Friends) Algorithm and the SubFind Algorithm.
I also played around with the positions halo objects and tried to observe the Large Scale Structure in the simulation. Due to the periodic boundaries, translating each particle by some value left or right or up or down while keeping the size of the box same, one can see that indeed, periodic boundary conditions are applied.
I also refined the plots where i was overplotting several types of particles on top of the other by separating them into several plots, one for each type and getting a much better and crisper picture.

0.2 Completed Exercises

0.2.1 Exercise 1

Exercise: Plot galaxy sizes vs stellar masses

First, I compared the various definitions for the size of the halo:

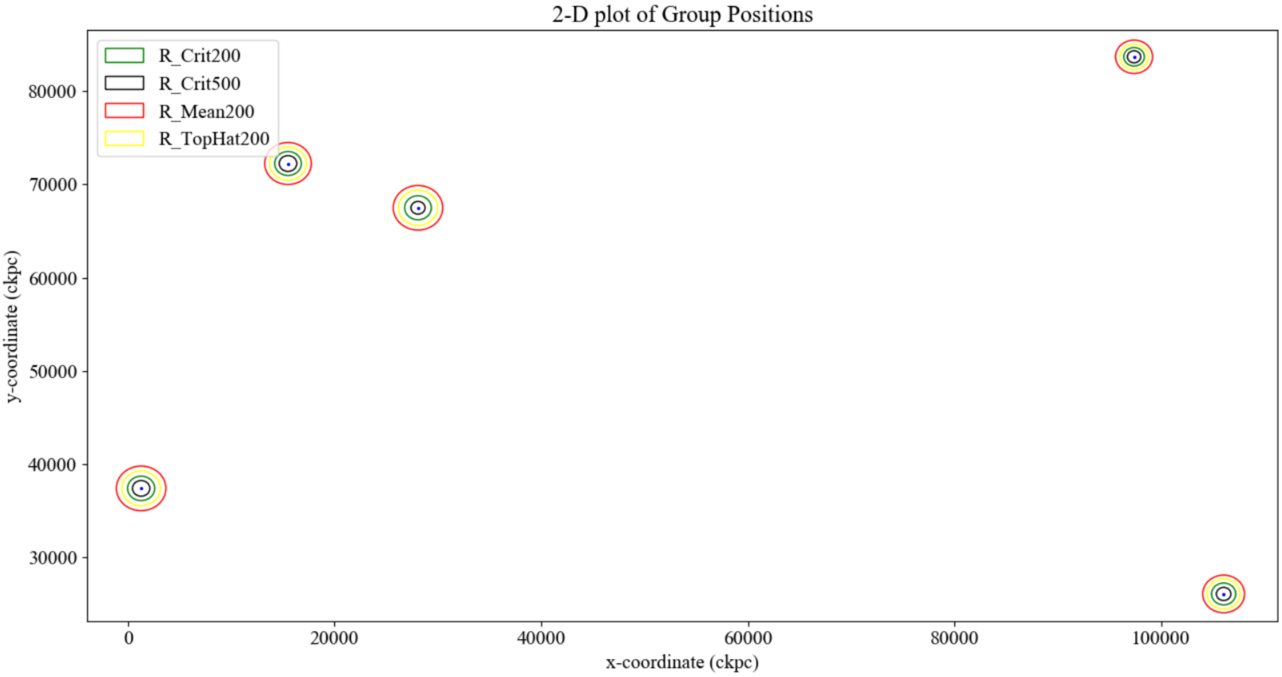

Figure 1: 2D Plot of some of the Halos along with various radii types

Then, zooming on one particular halo, we get:

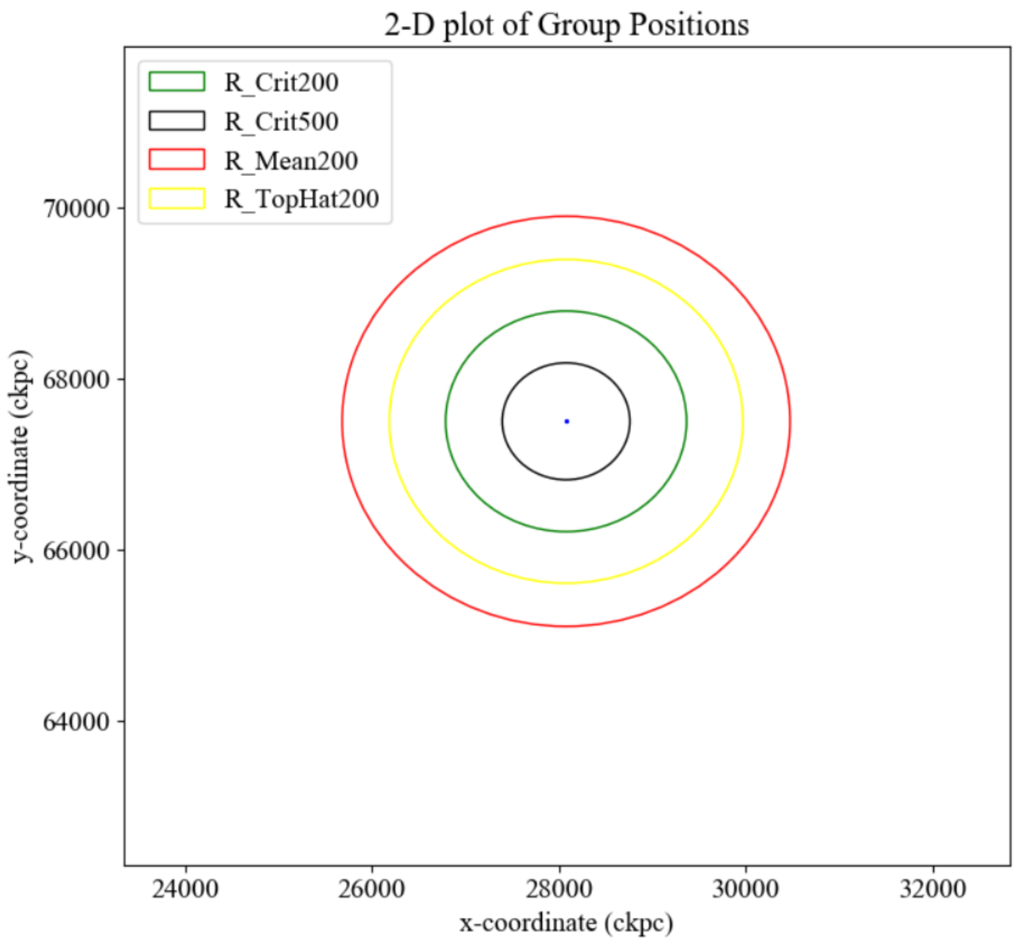

Figure 2: 2D Plot of a Halo along with various radii types

As one can see, the smallest is R_Crit500 which is defined to be the radius of the sphere, within which the density is 500 times the critical density (the density at which the expansion of the Universe has just stopped) of the universe at that redshift, which is theoretically given by:

$\rho_{cr}(z) = \frac{3H^2(z)}{8\pi G}$

where H(z) is the Hubble function.

Further, the next larger radii is the R_Crit200, which is defined to be the radius of the sphere, within which the density is 200 times the critical density of the universe at that redshift.

Next, we have the R_TopHat200, which is defined to be the radius of the sphere, within which the density is Δ_c times the critical density of the universe at that redshift, where the Δ_c is defined as the overdensity constant :
$\Delta_c = 18\pi^2 + 82x - 39x^2$
where $x = \Omega(z) - 1, \Omega(z) = \frac{\Omega_0(1+z)^3}{E(z)^2}, \Omega_0 = \frac{8\pi G\rho_0}{3H_0^2}$, and $E(z) = \frac{H(z)}{H_0}$
In the ΛCDM model, we have $\Delta_c \approx 100$.
And the largest of all, we have R_Mean200 which is defined to be the radius of the sphere, within which the density is 200 times the mean density of the universe at that redshift.

Having done this, I compare the masses and the sizes of the halo for the various radii types that we have seen:

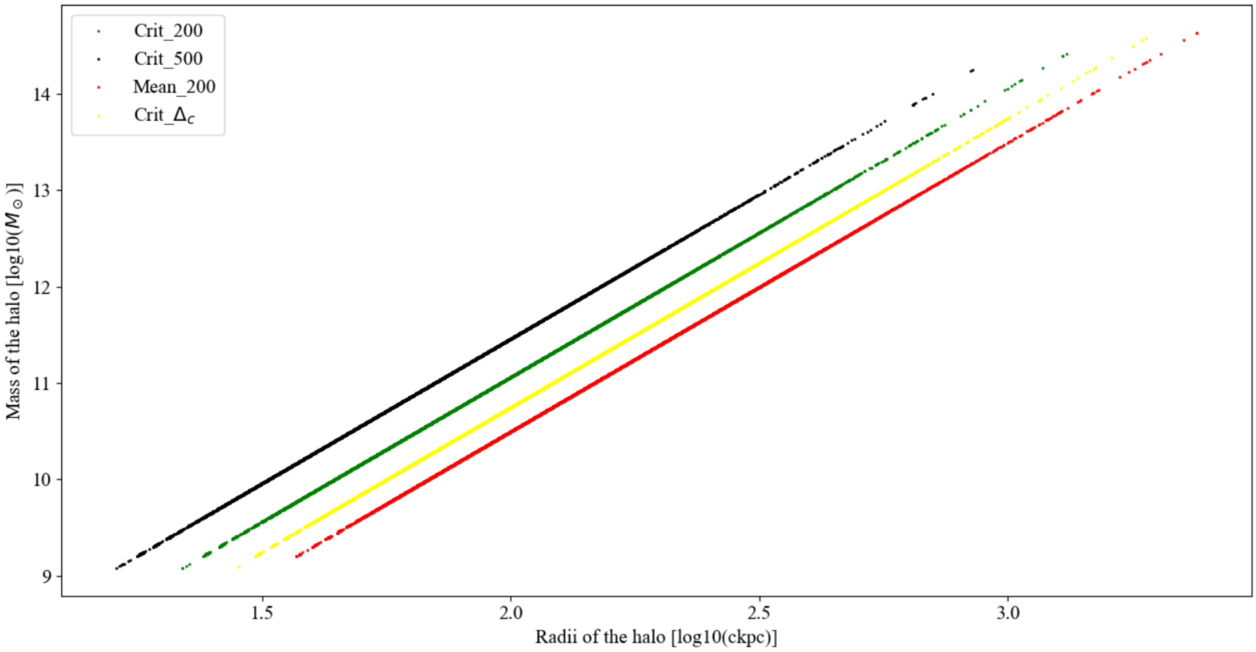

Figure 3: Mass of halo Vs Size of Halo for various Radii types (log scale)

After this, I plot the Dark Matter and Stellar masses for various Subhalos using SubhaloMassType. The first plot is just a simple plot of the Dark matter mass (blue) and Stellar Mass (red) on a logarithmic scale for the mass as a function of the distance from the origin of the periodic box. The second plot is of the ratio of the Dark Matter Mass and the Stellar Mass for each Subhalo entry in the logarithmic scale again, as a function of the distance from the origin of the periodic box.

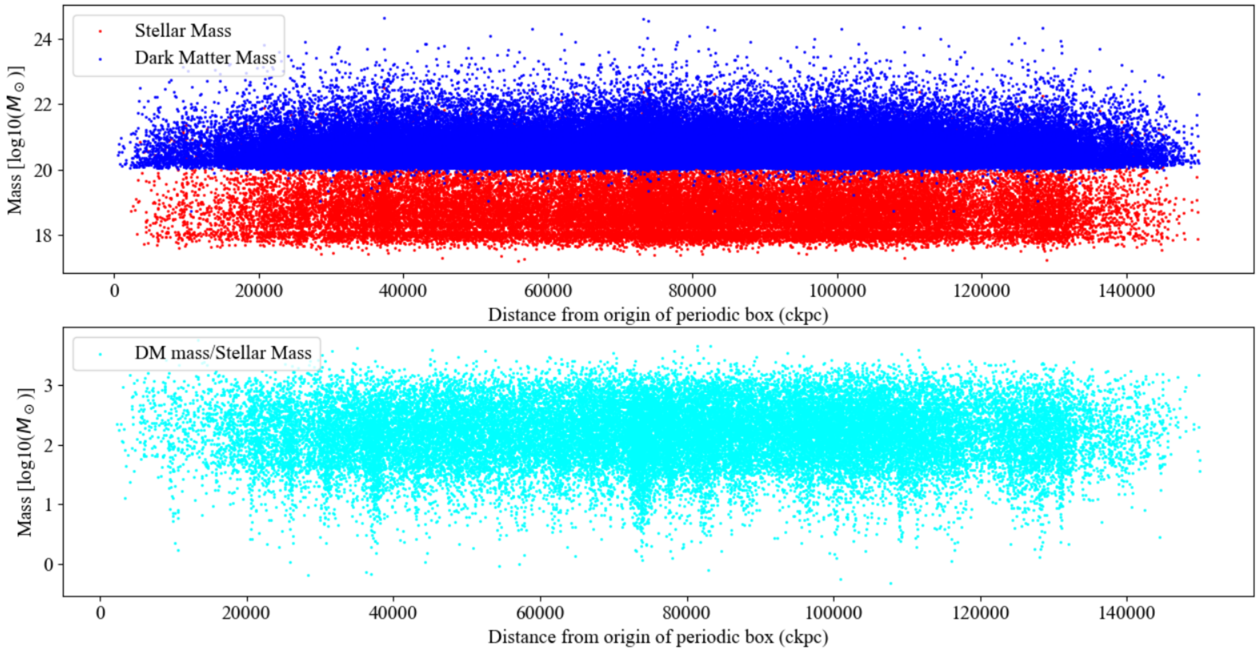

Figure 4: Dark Matter and Stellar Masses

As one can see, for most of the cases, the Dark Matter mass is significantly higher (upto 3 orders of magnitude) than the Stellar Mass. This is evident from observing both the graphs and comparing the masses in the logarithmic scale.

0.2.2 Exercise 2

Exercise: Plot: Mgas vs Mhalo I redo the plot using pre-processed values of the Halo/Subhalo and Gas masses from the Halocatalog file and plot the graph on a logarithmic scale for both the Halos as well as Subhalos:

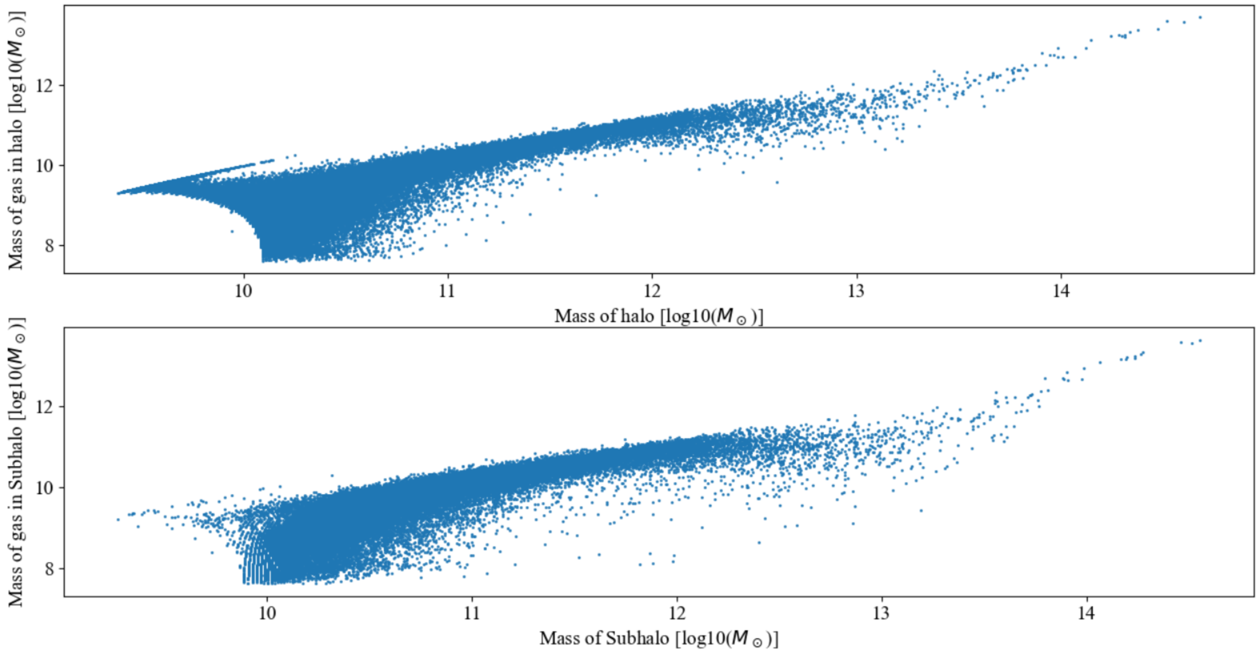

Figure 5: Mass of Gas vs Mass of Halo/Subhalo

We see an almost linear curve in both the cases with high Mean Squared error in the initial mass range which tapers towards the end. This shows that as the mass of the galaxy increases the ratio of the total mass of the Gas and the mass of the galaxy remains nearly constant.

0.2.3 Exercise A1

Exercise: Plot the radial distribution of sub halos around halos of a given mass.

I first took the First Group in the Halocatalog and plotted the center (GroupPos) and the Virial Radius (Group_R_Crit200) and plotted all the subhalo entities inside this radius.

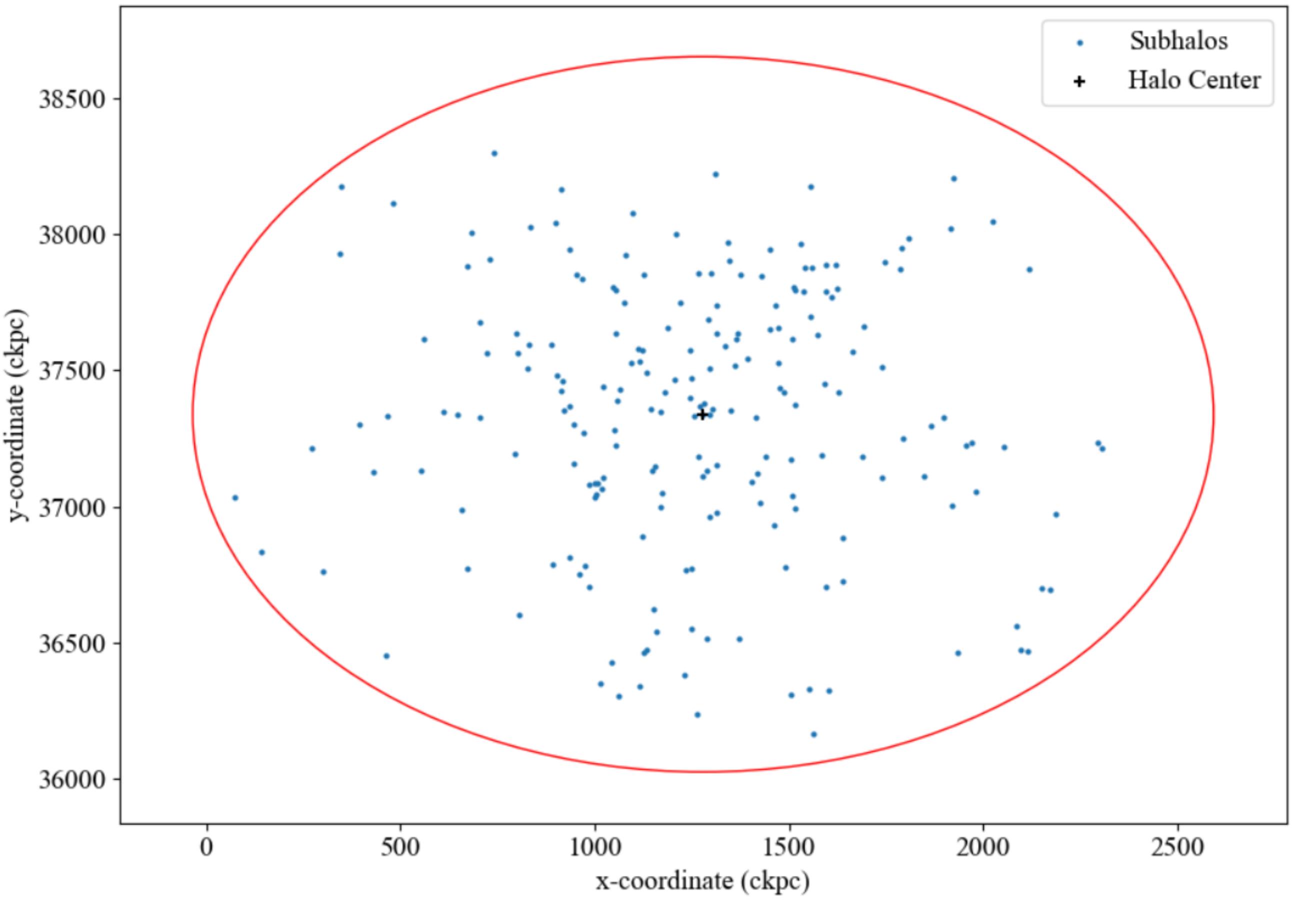

Figure 6: Subhalo entities inside the Virial Radius of a Group

Then, I plotted the number (1st plot) and the cumulative number (2nd plot) of subhaloes vs the 3D Distance from the center of the Group as a histogram with 20 bins.

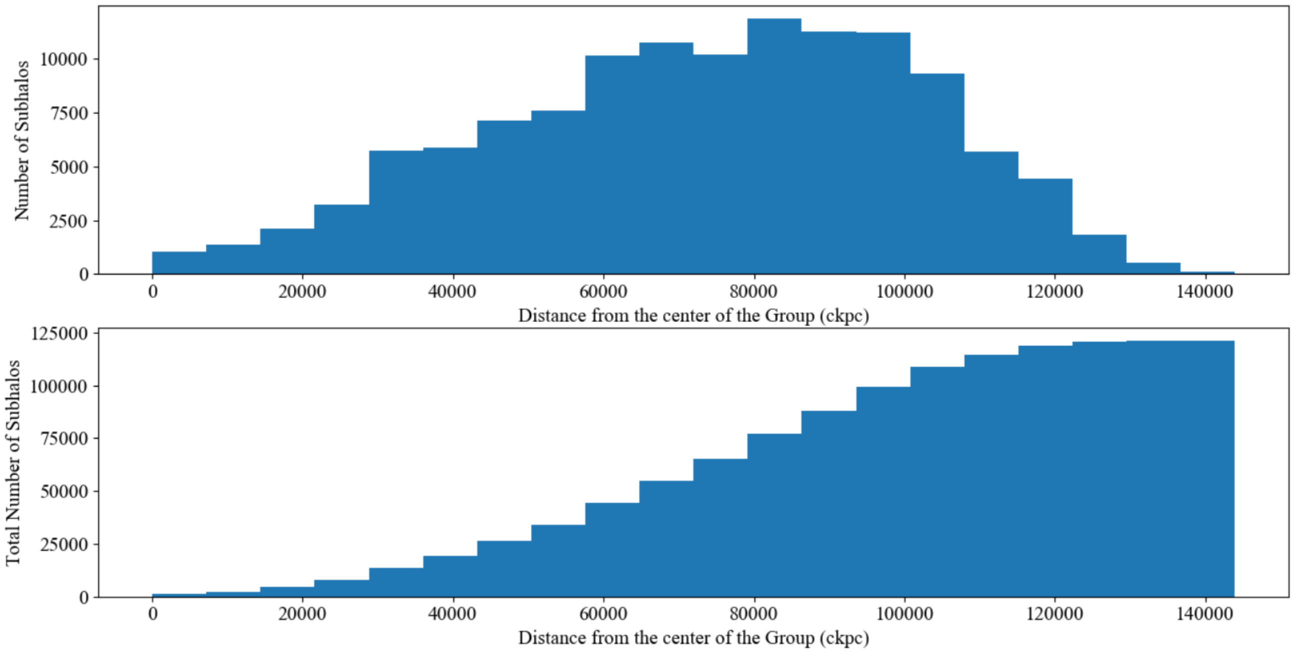

Figure 7: Number of Subhalos vs Distance from center of the Group

As one can see from the cumulative histogram, the number is nearly constant towards the end.

0.2.4 Exercise 3

Exercise: Load the particles of a Halo as Group, load the particles of its central SUBFIND halo. Of those particles, take the coordinates and plot them.

I redid the earlier plot by separating the particle types and plotted 4 different plots to see the distribution of each type individually. I have also reduced the size of each particle in the plot.

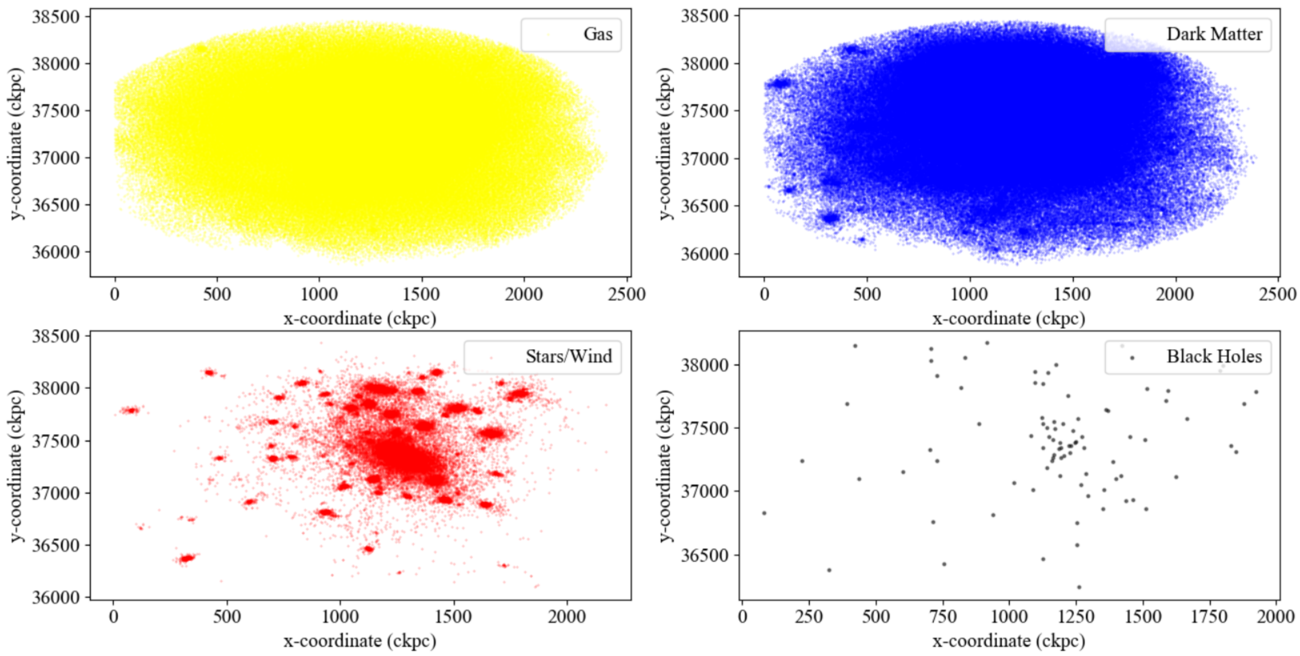

Figure 8: 2D Plot of Particles of Central Halo

For finding which particle belongs to FoF algorithm and which belongs to the SubFind algorithm, I have got the gist of it, where I have to use the SubhaloGrNr attribute (which gives the index into the Group table of the FoF host) and the SubhaloParent attribute (which gives the index into the Group table of the SubFind parent) and plot them correspondingly, am yet to write the code for it.

0.2.5 Exercise 4

Exercise: Load particles of a whole volume of a small sim (one chunk after after the other): plot their positions (2D) projection and overplot the positions of haloes

I first separated the particle types and plotted each of them over the Halo positions.

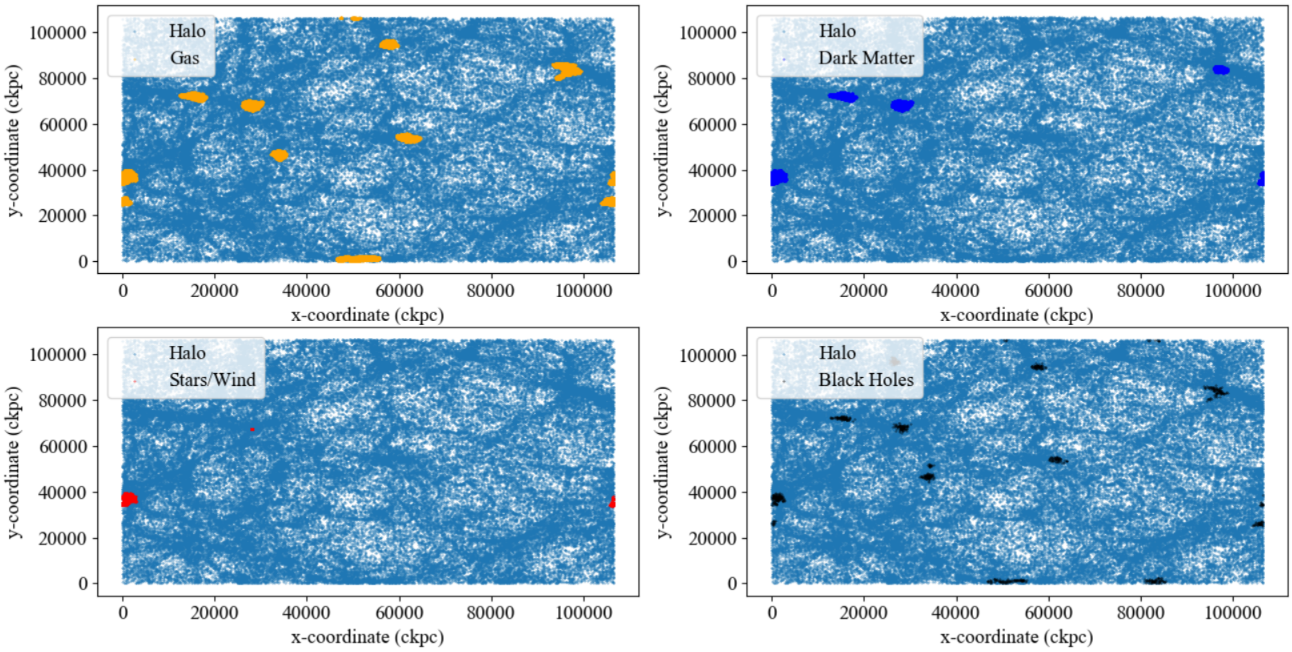

Figure 9: 2D Plot of All particles plus halo overplotted

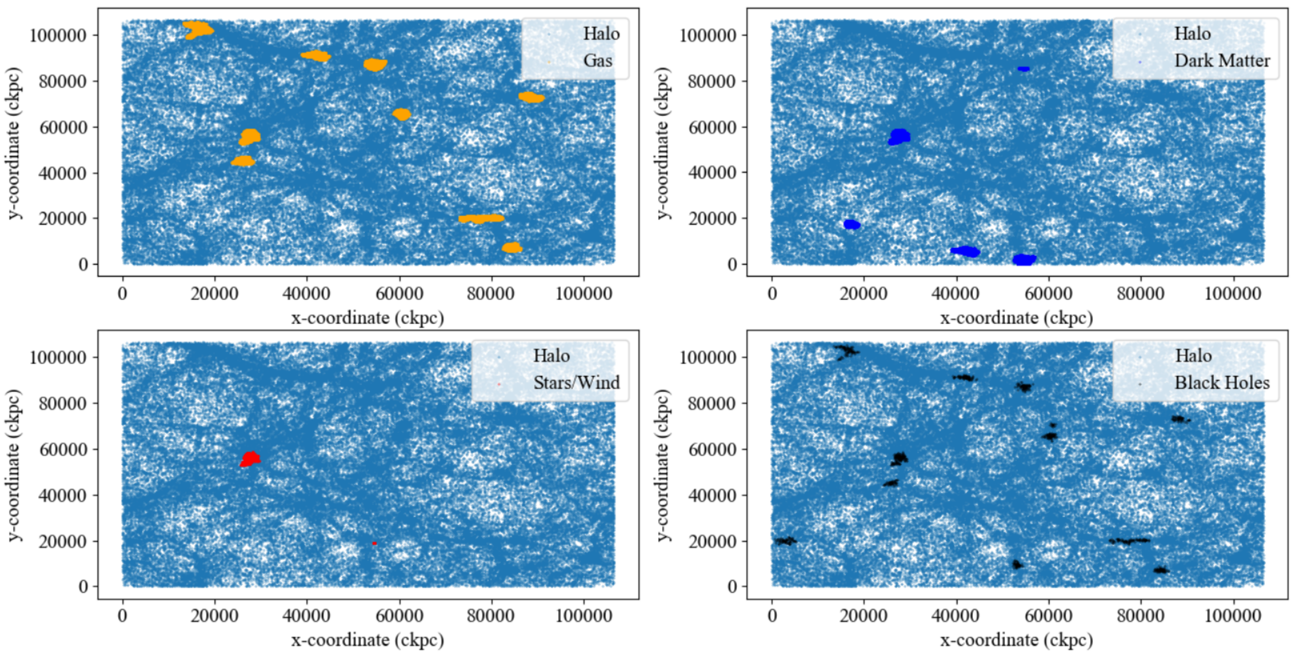

Figure 10: 2D Plot of All particles plus halo overplotted and shifted

One can see the continuation of the Large Scale Structure (formed by the Halo Background) and of the entities formed by each of the particle types (Gas, DM,etc) across the boundary of the image. To further test this periodic boundary condition, I displace each particle to the left by around 20,000 ckpc and down by around 19,000 ckpc and got the second plot. As can be seen, the filamental background structure has shifted without any discrepancies and has a smooth continuation, thus showing periodic boundary conditions.