# Density Distribution of Dark Matter Subhaloes

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## INTRODUCTION

***Why dark matter?***

- The data from several astronomical observations cannot be explained unless a mysterious matter—dark matter (DM)—is added.
- The word *dark* means DM does not interact with light (electromagnetic wave).

***Our Universe ≈ 5% baryons + 26% dark matter + 69% dark energy***

***What is dark matter?***

- The physical identity of DM, whether it is particle or not, is still unknown
- Several theoretical models have been created but none of them are fully testified so far
- The Standard Model cannot explain DM particles

**Cold dark matter (CDM)**

- a hypothetical model of DM
- Newtonian gravity is the only interaction between two DM particles

**Self-interacting dark matter (SIDM)**

- a hypothetical model of DM
- In addition to Newtonian gravity, there is another interaction between two DM particles: self-interaction
- The form of the self-interaction, whether it is repulsive or attractive, is unknown so far

***What is dark matter halo and subhalo?***

- The galaxy, such as Milky Way, is surrounded by dark matter which is called dark matter halo
- Due to Newtonian gravity, the shape of the DM halo is roughly a sphere
- The size of the DM halo is huge compare to its central galaxy
- The subhalo is the DM halo around the satellite galaxy

***"Cusp/core problem" ?***

- An inconsistency between observations and CDM model
- CDM model shows that the density of the DM subhaloes rises steeply, or is "cuspy," in its central part. However, the density of the observed satellite subhaloes of the Milky Way is low and roughly constant, or "core"-like.
- Possible solutions include SIDM and/or taking count of tidal effects
- Identifying the effects of different parameters to the density distribution can solve the core collapse problem

## AIM

- Investigate the DM density distribution of the subhalo; set the initial density distribution as NFW profile

$$\rho_{\mathrm{NFW}}(r) = \frac{\delta_c \rho_{\mathrm{critical}}}{\frac{r}{r_s}\left(1+\frac{r}{r_s}\right)^2}$$

- Compare the time-evolution of density distribution between CDM subhalo and SIDM subhalo, especially for central part
- Identify initial velocity's effects on the evolution of density distribution
- Visualize the DM halo and DM subhlao

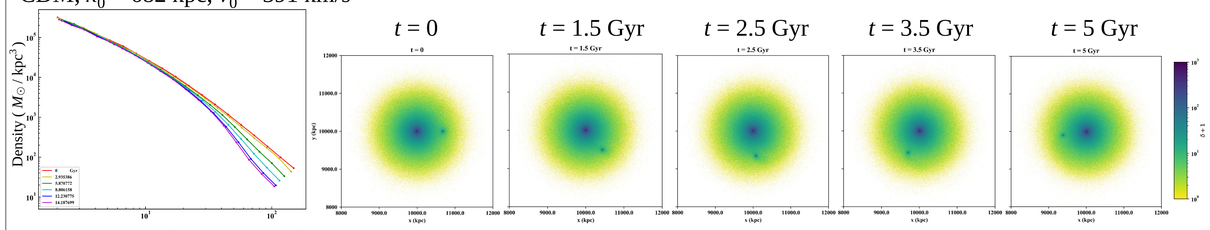
**Our results along with observation data can help to identify the nature of dark matter, i.e. CDM or SIDM.**

## TOOLS

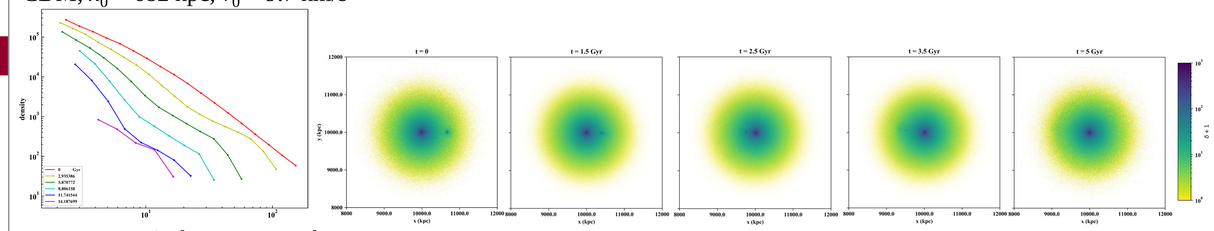
- Ohio Supercomputer Center
- AREPO
  a new cosmological hydrodynamical simulation code on a fully dynamic unstructured mesh
- spherIC
  initial conditions generator
- Amiga's Halo Finder (AHF)
  a program to analyze DM halo data
- C, C++, and Python3 programming languages

## RESULTS

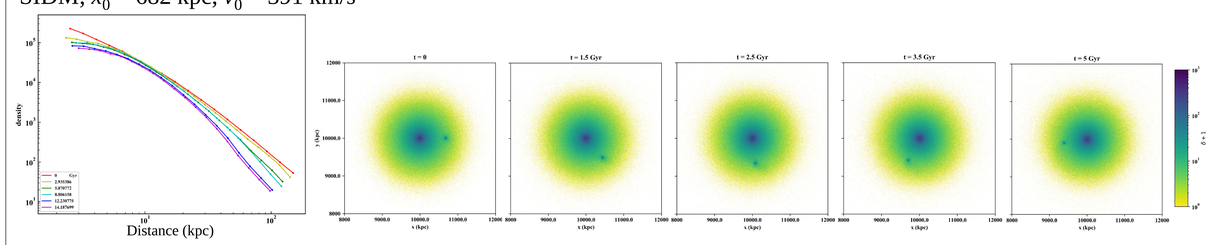
CDM; $x_0$ = 682 kpc, $v_0$ = 391 km/s




CDM; $x_0$ = 682 kpc, $v_0$ = 9.7 km/s




SIDM; $x_0$ = 682 kpc, $v_0$ = 391 km/s




## CONCLUSIONS

- Self-interaction can cause a relatively-constant-density core at the center of the DM subhalo
- The initial velocity of DM subhalo relative to DM halo, or equivalently the pericenter of DM subhalo, has a significant effect on density evolution
- Small initial velocity means smaller pericenter; due to gravity, the subhalo will eventually disappear after experiencing mass lost and density distribution changes

## NEXT

- Investigate the effects of differential cross section, constant or velocity-dependent, of SIDM on density distribution
- Investigate the effects of concentration on density distribution
- Investigate the effects of self-interaction by setting CDM halo with SIDM subhalo
- Study the orbit of subhalo in NFW potential and other potential fields
- Along with possible astronomical data, our results can help to identify the nature of dark matter

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