

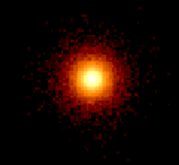
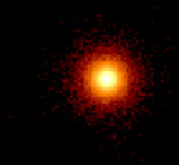
# The Effect of Dark Substructures on Stellar Tidal Streams

Margot Pernet, M2 student, Observatoire Astronomique de Strasbourg

Supervisors : Raphael Errani, Jonathan Freundlich

Smooth halo

$N_{\text{sub}}/N_{\text{tot}} = 100\%$



t=0.0 Gyrs

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# I. Introduction – General Context

## ➤ $\Lambda$ CDM model :



*Frenk & White 2012*

- Low mass DM substructures

# I. Introduction – General Context

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- Low mass DM substructures
- No stars

*Frenk & White 2012*

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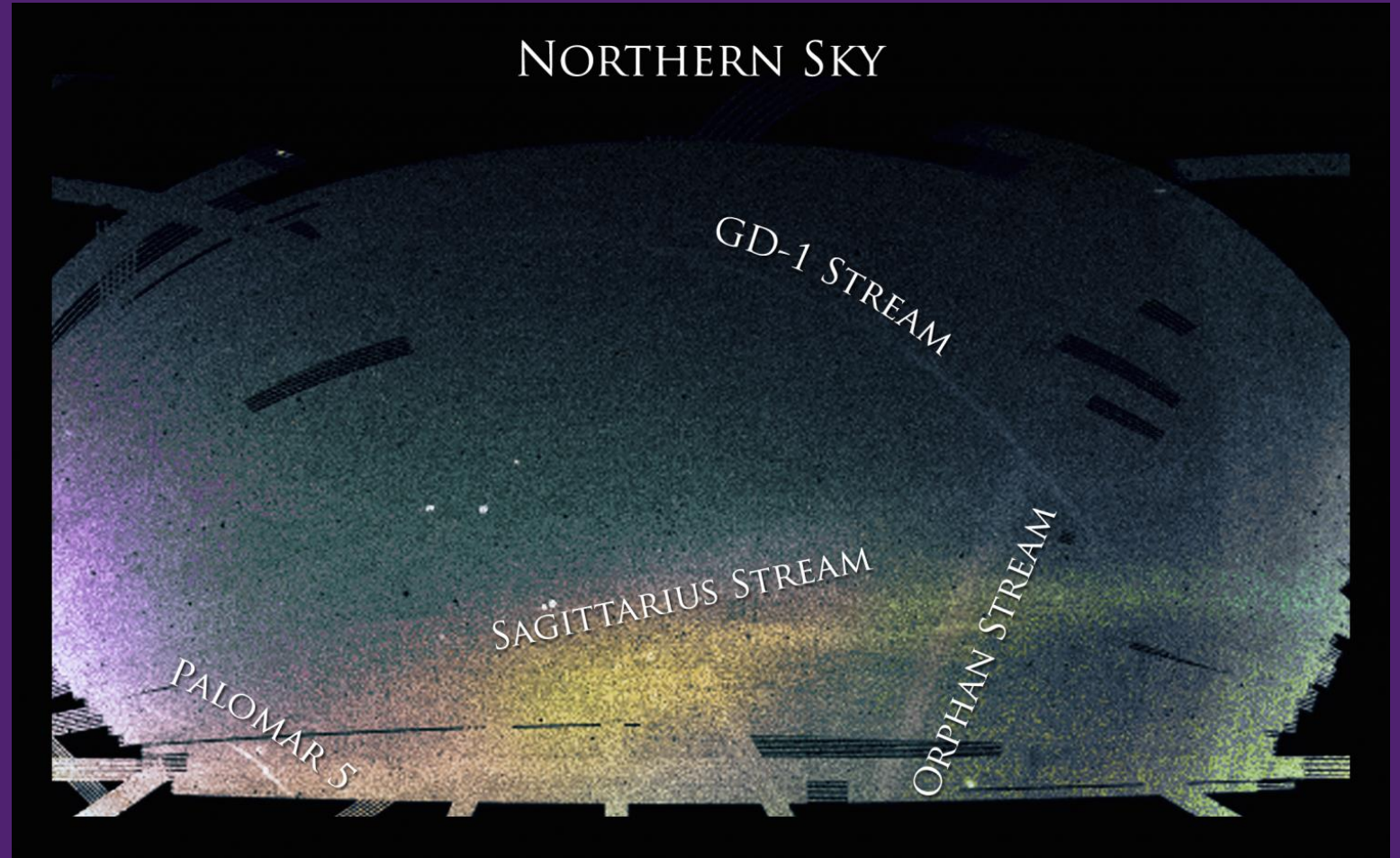
➤ How to detect ?



# I. Introduction – Aim and hypothesis

## ➤ Stellar Streams :

- GC or DG disruption

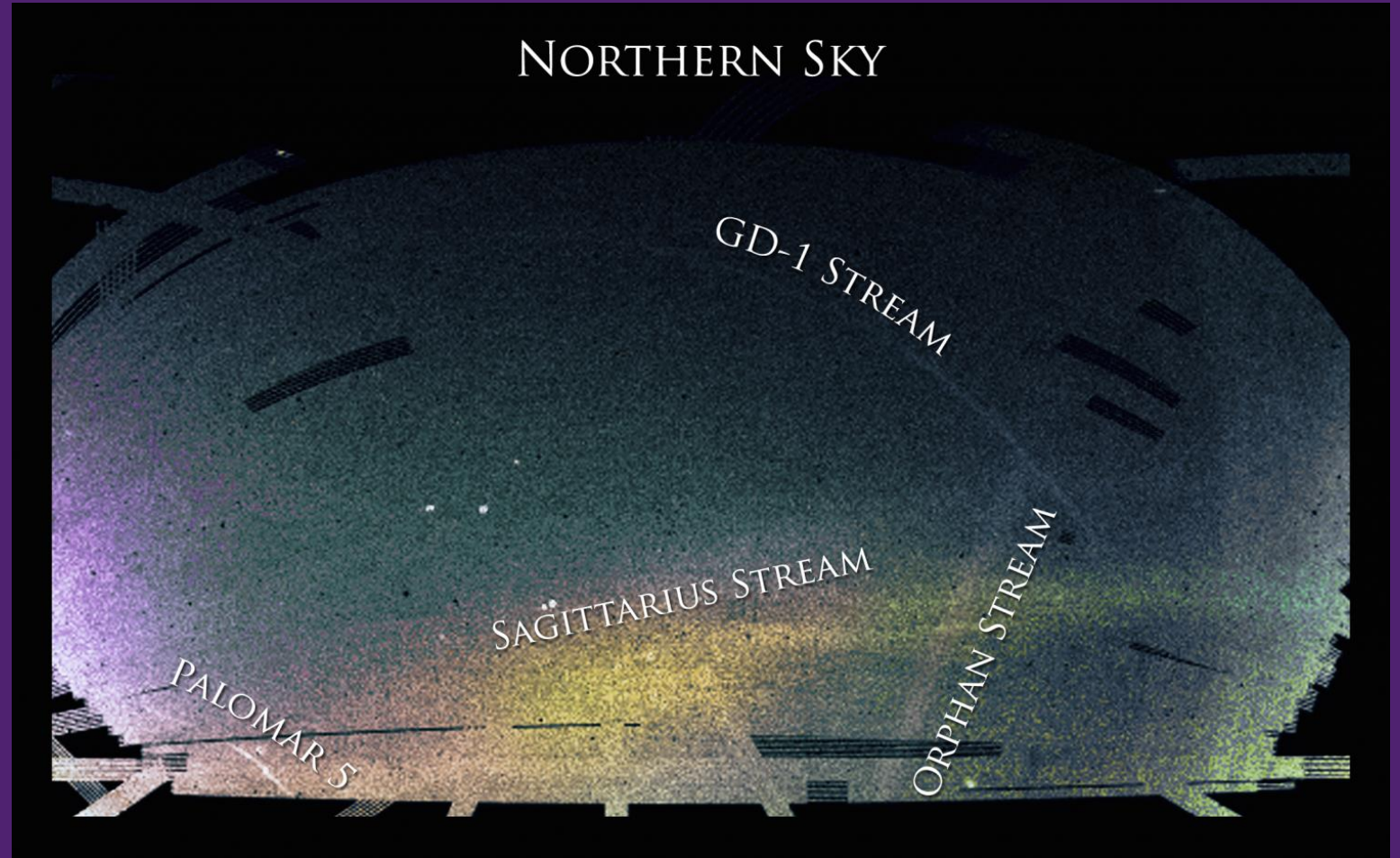


*Ana Bonaca, Vasily Belokurov, SDSS Sloan Digital Sky Survey*

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- Cold and easily perturbed



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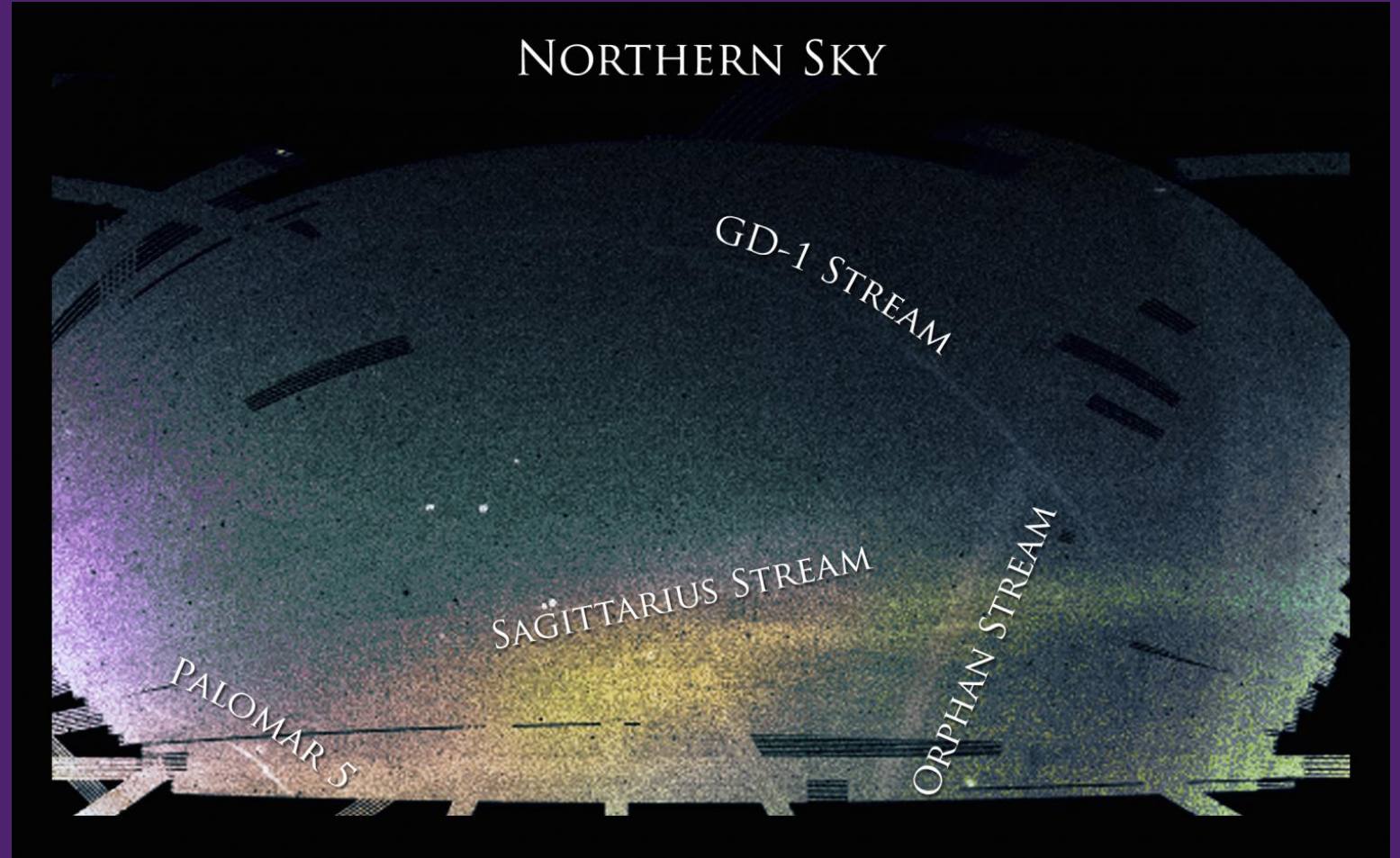


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## ➤ Stellar Streams :

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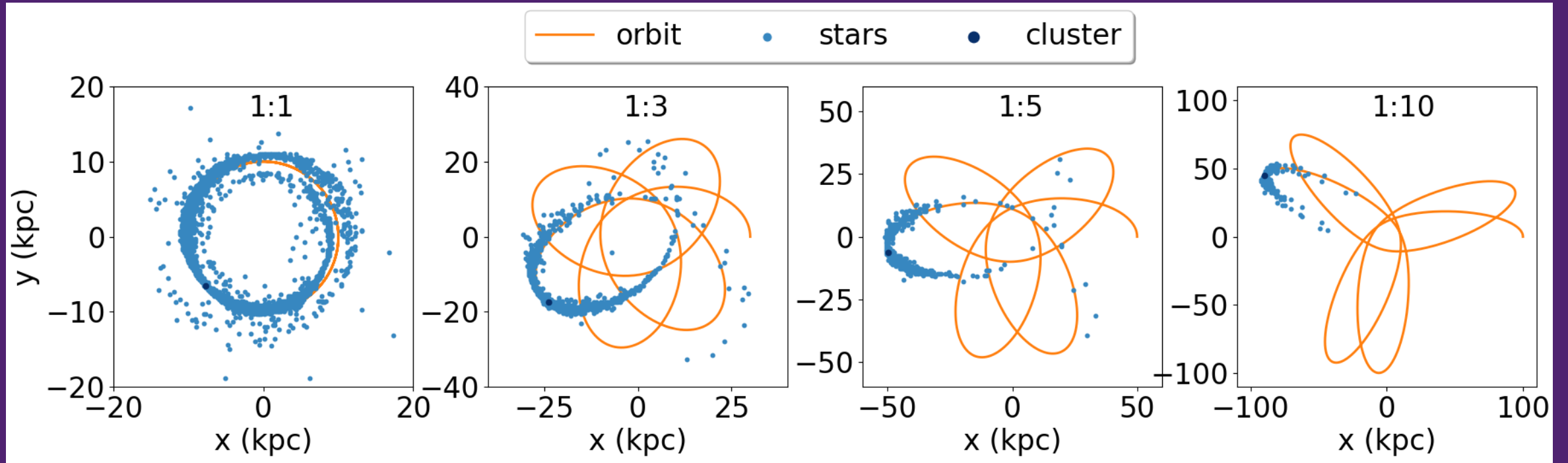
## ➤ DM substructures !



*Ana Bonaca, Vasily Belokurov, SDSS Sloan Digital Sky Survey*

## II. Modelling – Streams

➤ All orbits : GC Plummer sphere

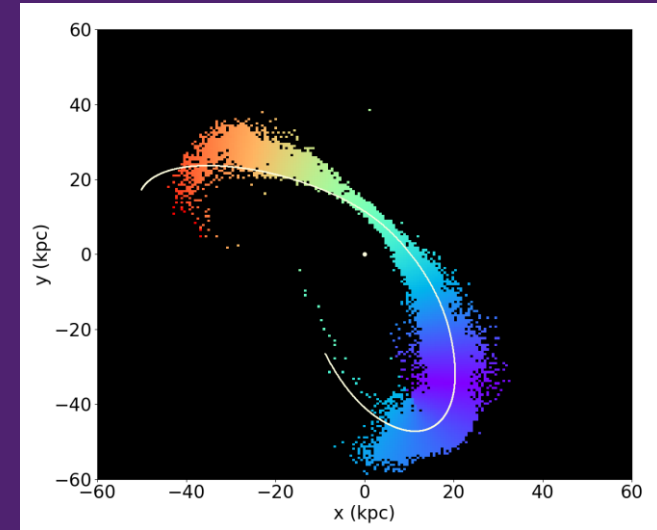


## II. Modelling – Stream coordinates

Equations :

$$l_{*0} = 0$$

$$l_{*i} = \sqrt{(x_{orbit\ i} - x_{orbit\ i-1})^2 + (y_{orbit\ i} - y_{orbit\ i-1})^2}$$



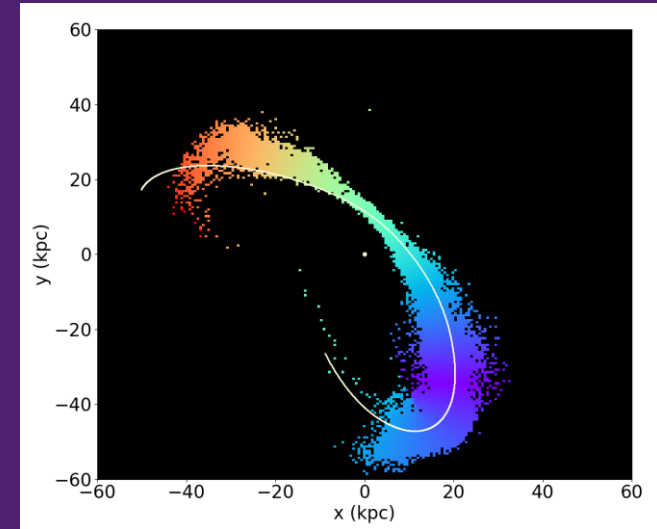
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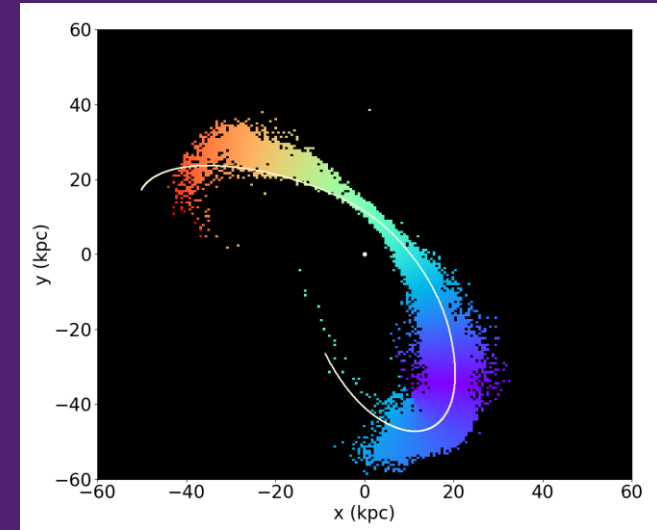
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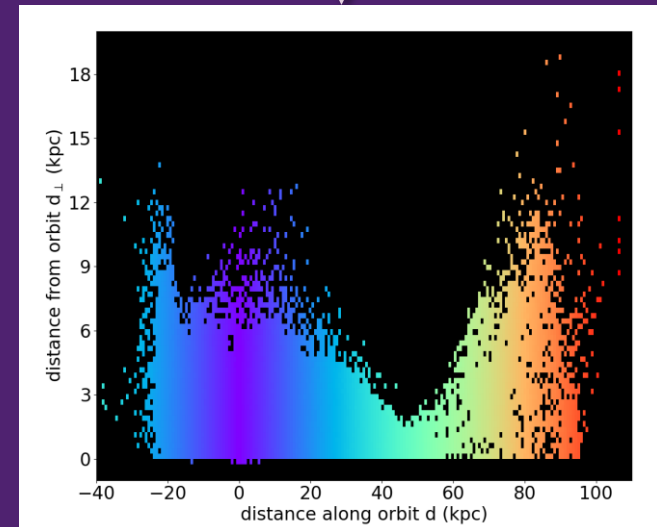
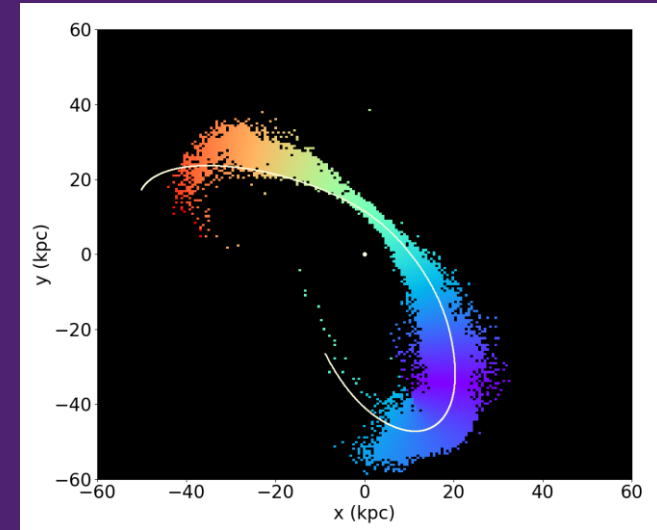
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## II. Modelling – Full scheme

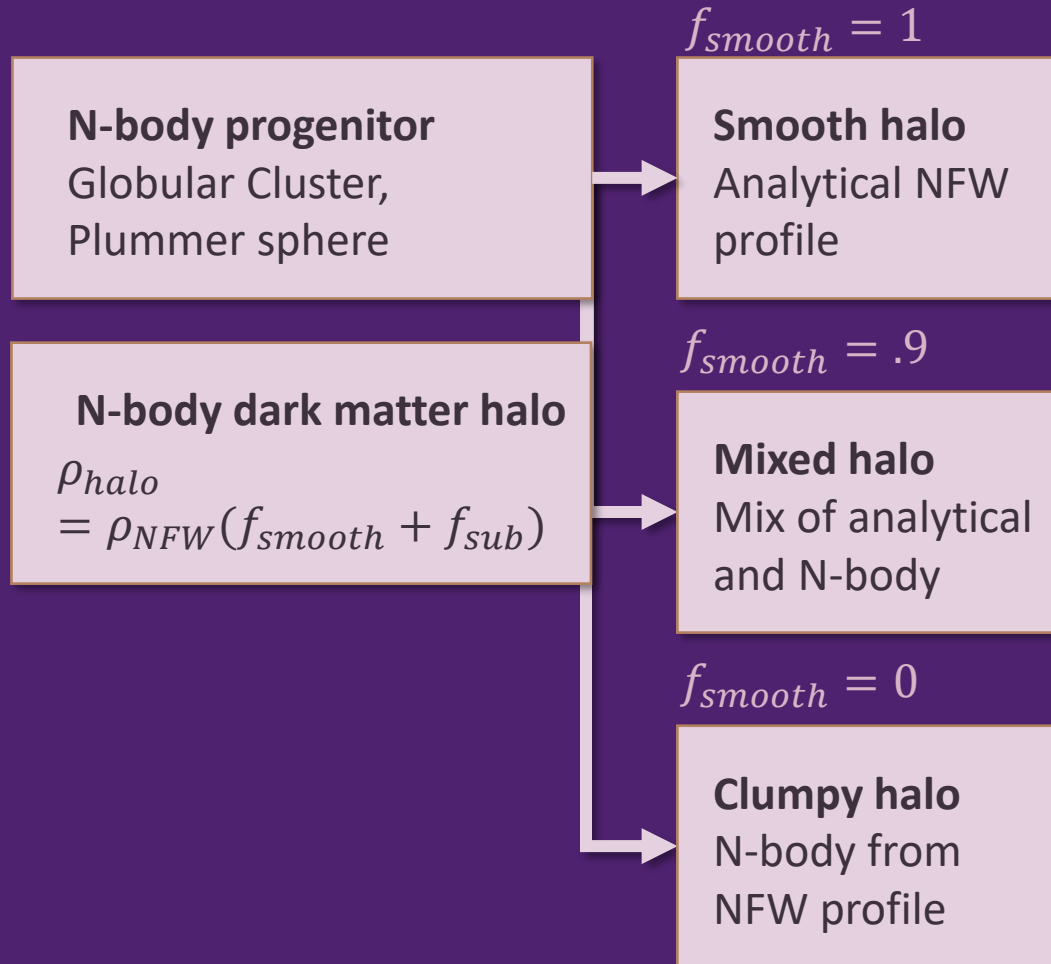
### **N-body progenitor**

Globular Cluster,  
Plummer sphere

### **N-body dark matter halo**

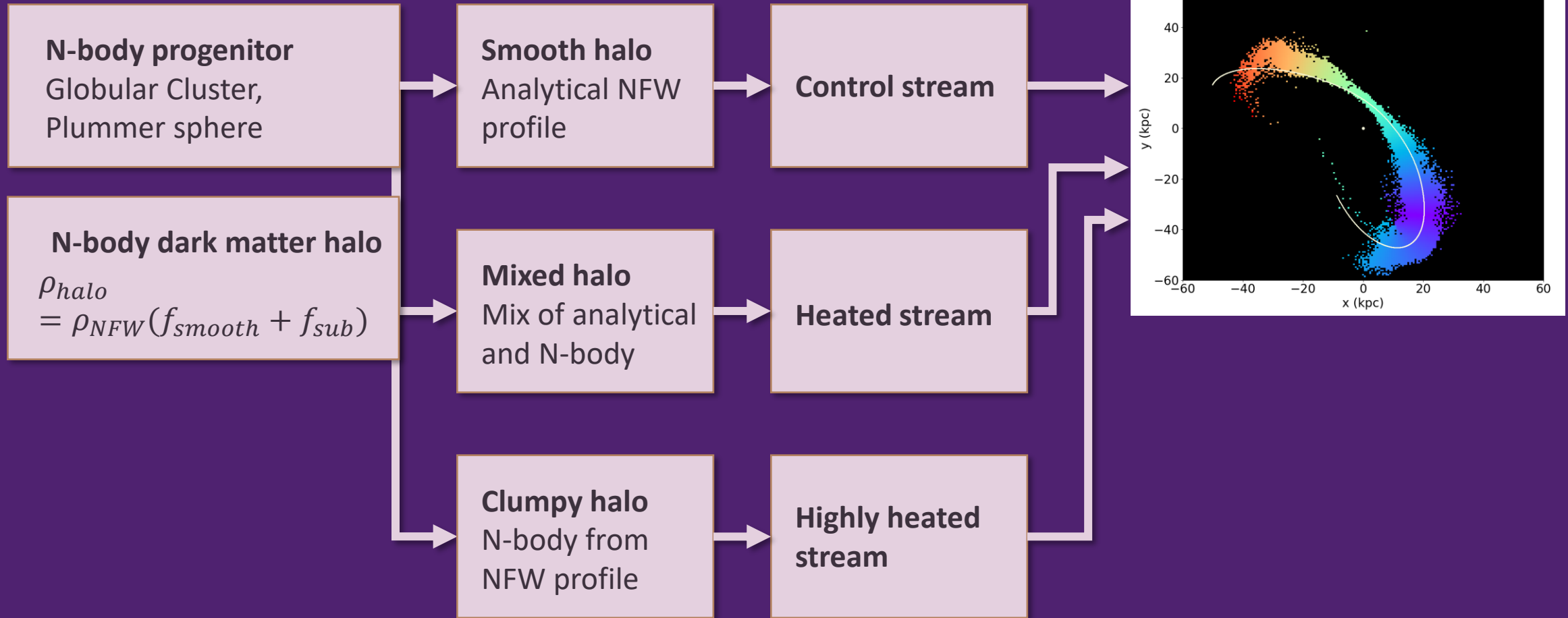
$$\rho_{halo} = \rho_{NFW}(f_{smooth} + f_{sub})$$

## II. Modelling – Full scheme

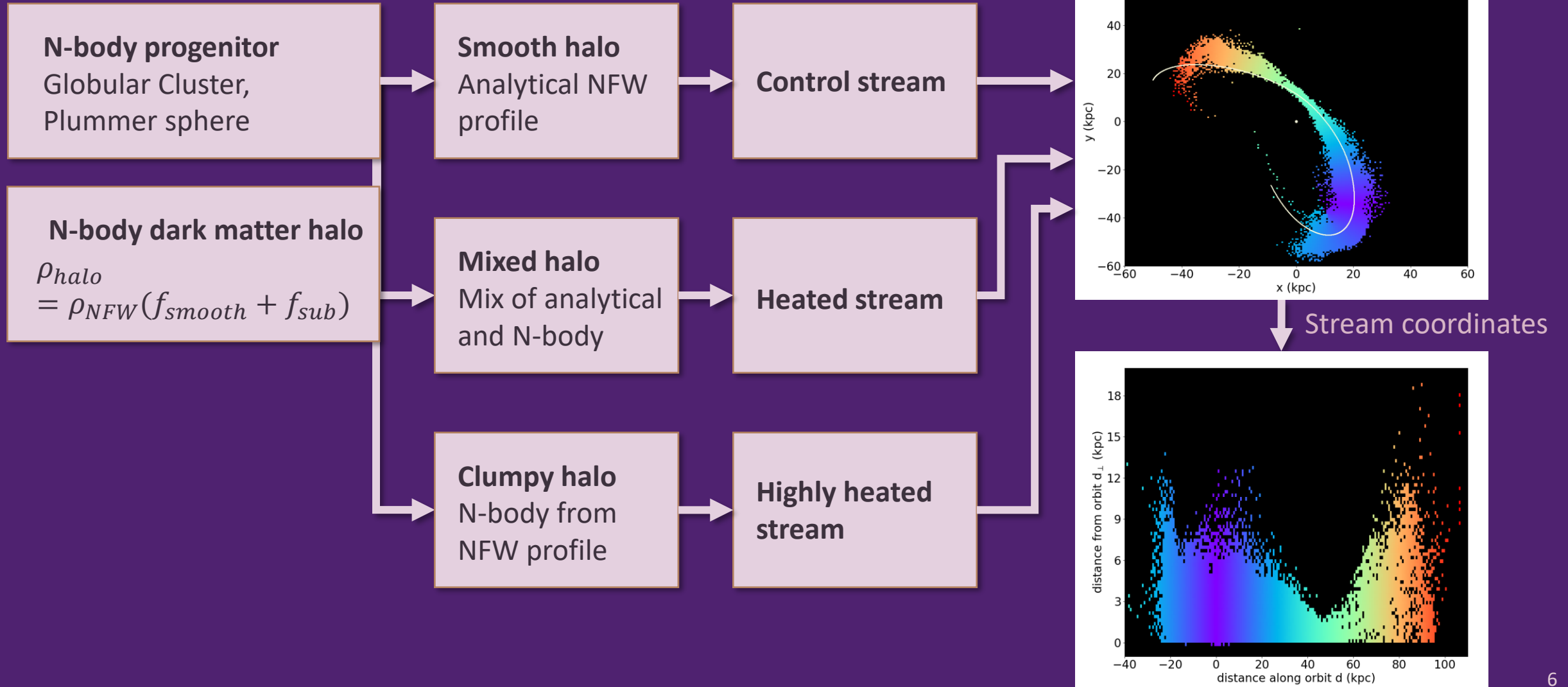




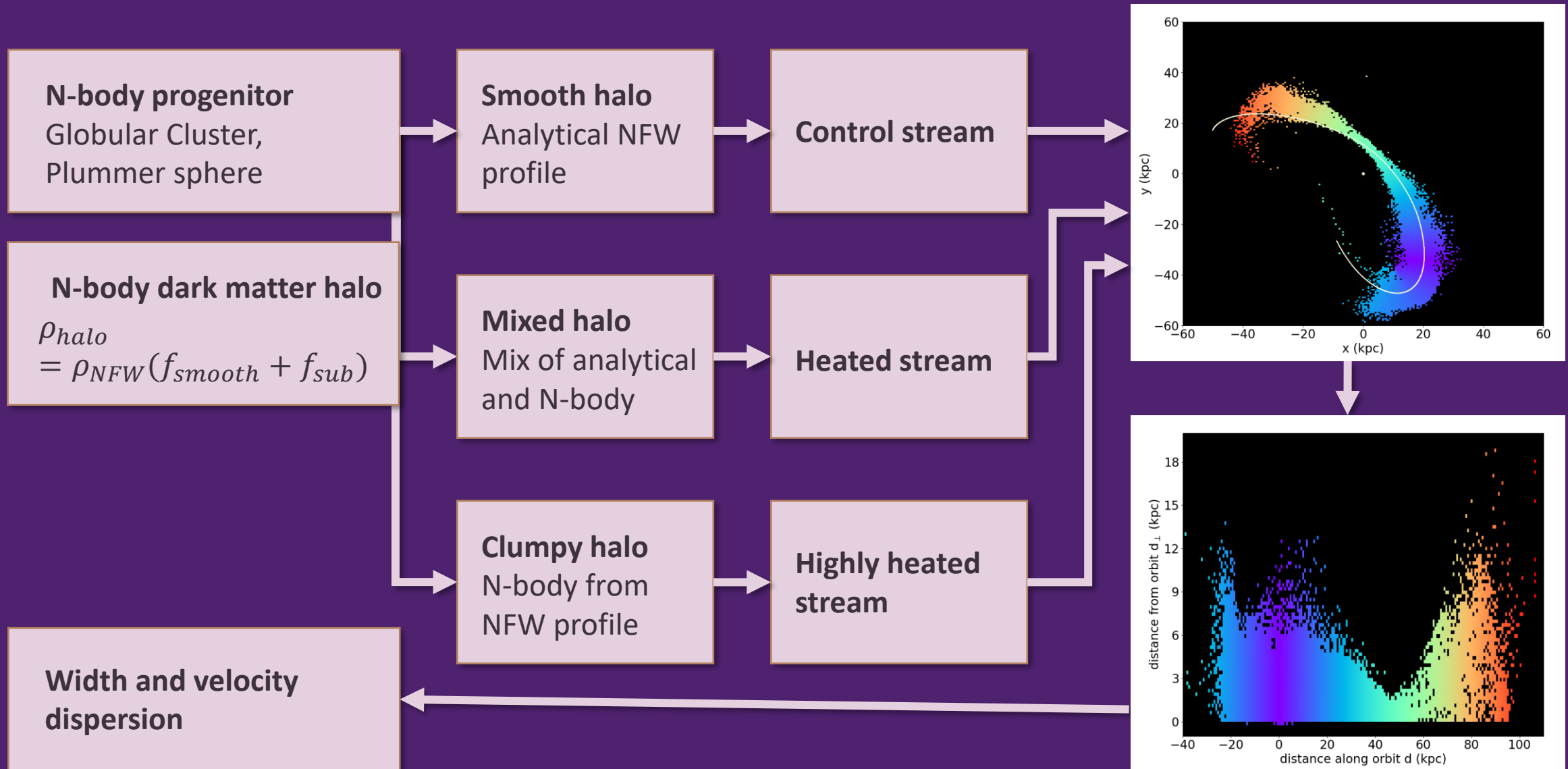
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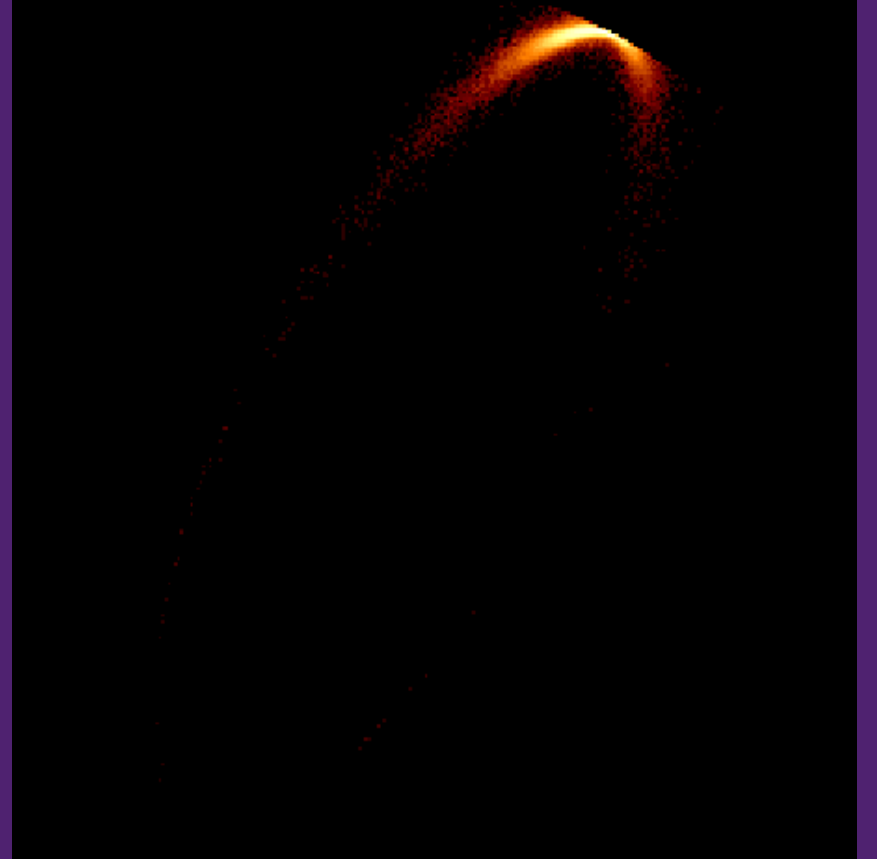
## II. Modelling – Full scheme



## II. Modelling – Parameters

### ➤ Parameter space :

- Number of substructures

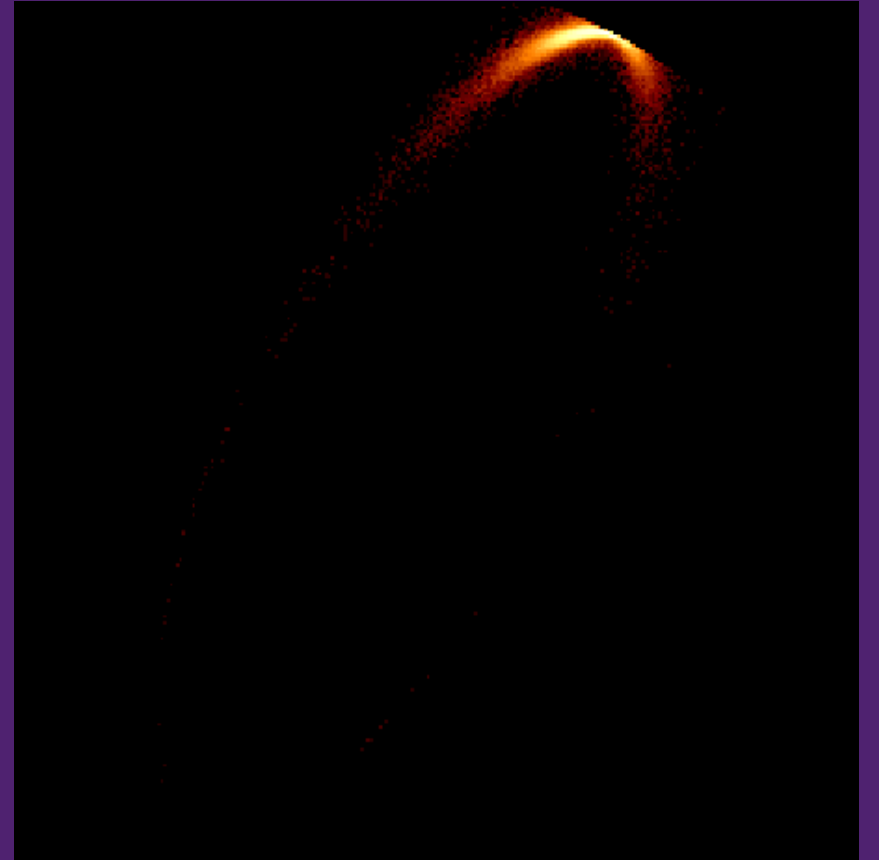




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### ➤ Parameter space :

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### ➤ Parameter space :

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- Mass of substructures
- Size of substructures

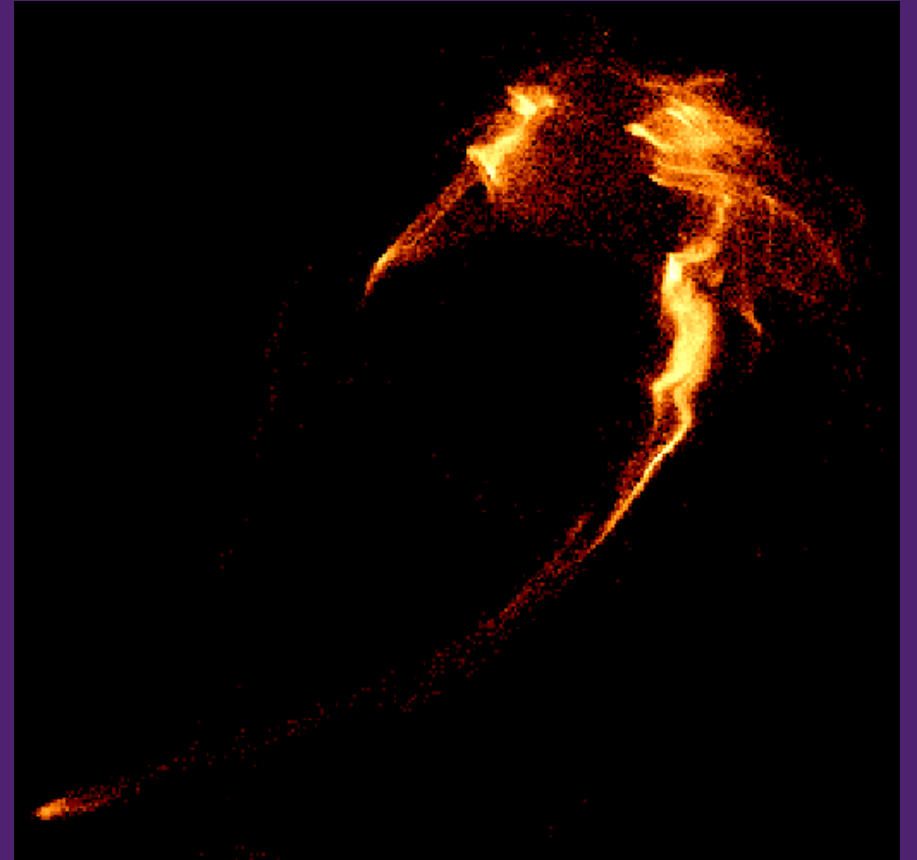


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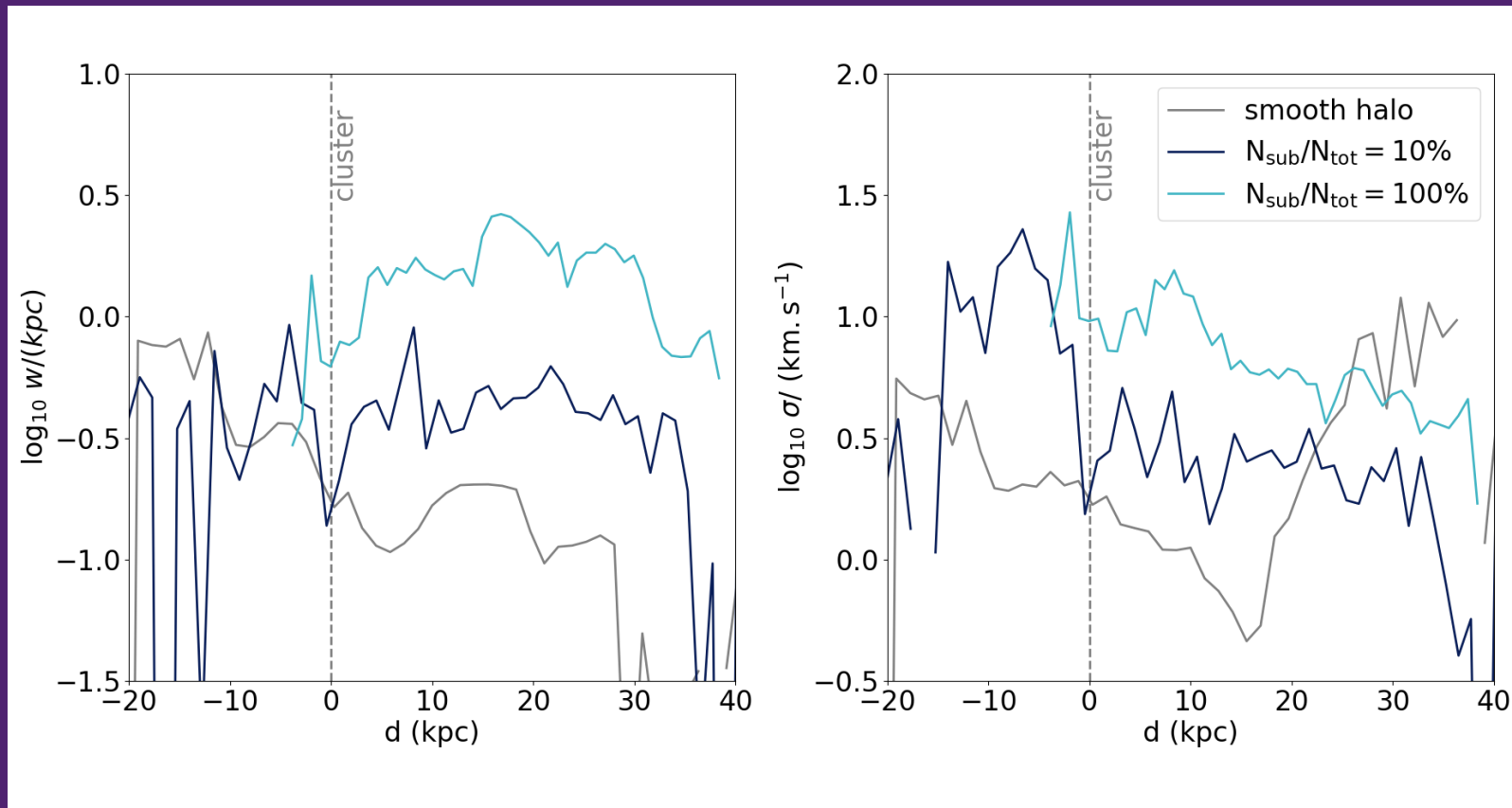
### ➤ Characterization of heating!



## II. Modelling – Results

### ➤ Substructure Number :

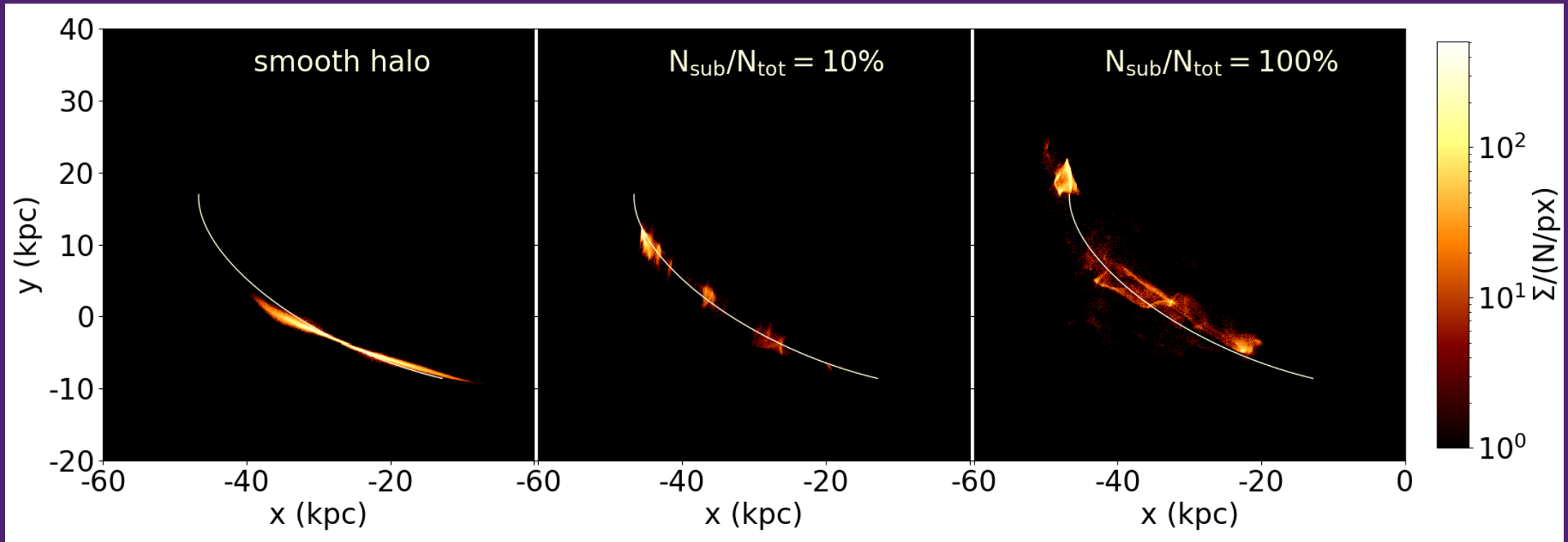
- Visible heating



## II. Modelling – Results

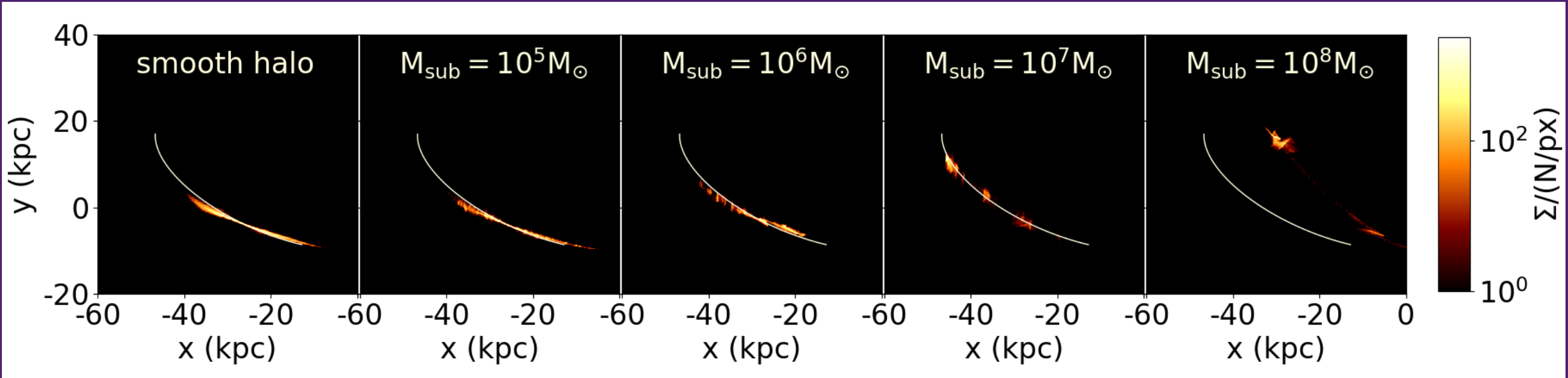
### ➤ Substructure Number :

- Visible heating
- Varied structure



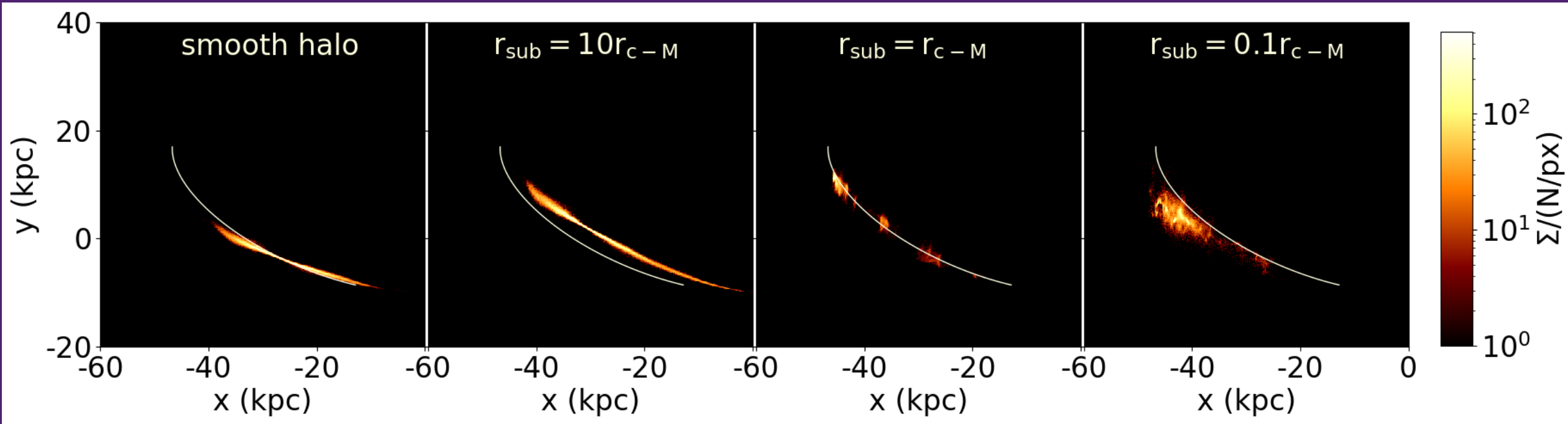
## II. Modelling – Results

### ➤ Substructure Mass :



## II. Modelling – Results

### ➤ Substructure Size :

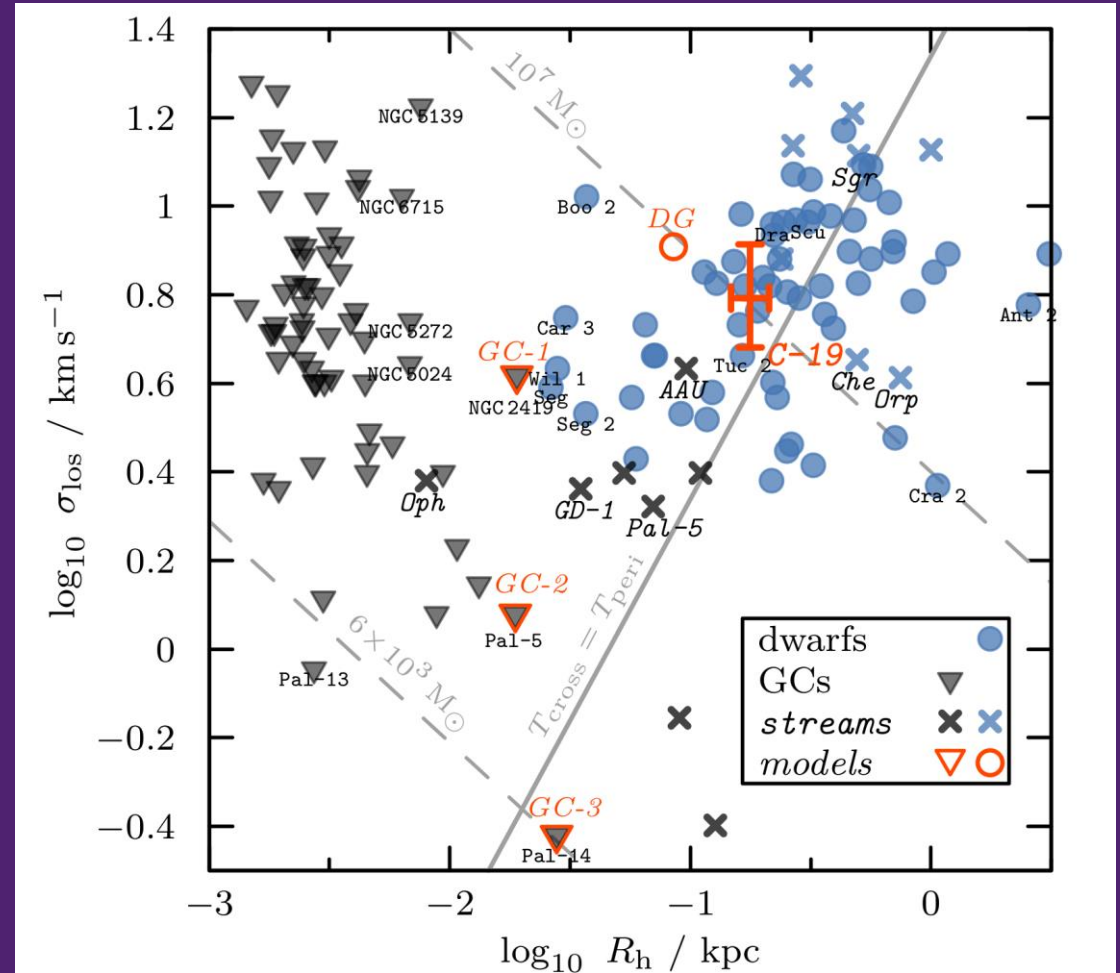




# III. Discussion – Application

## ➤ Application to C-19

- Why ?
  - Progenitor mystery...

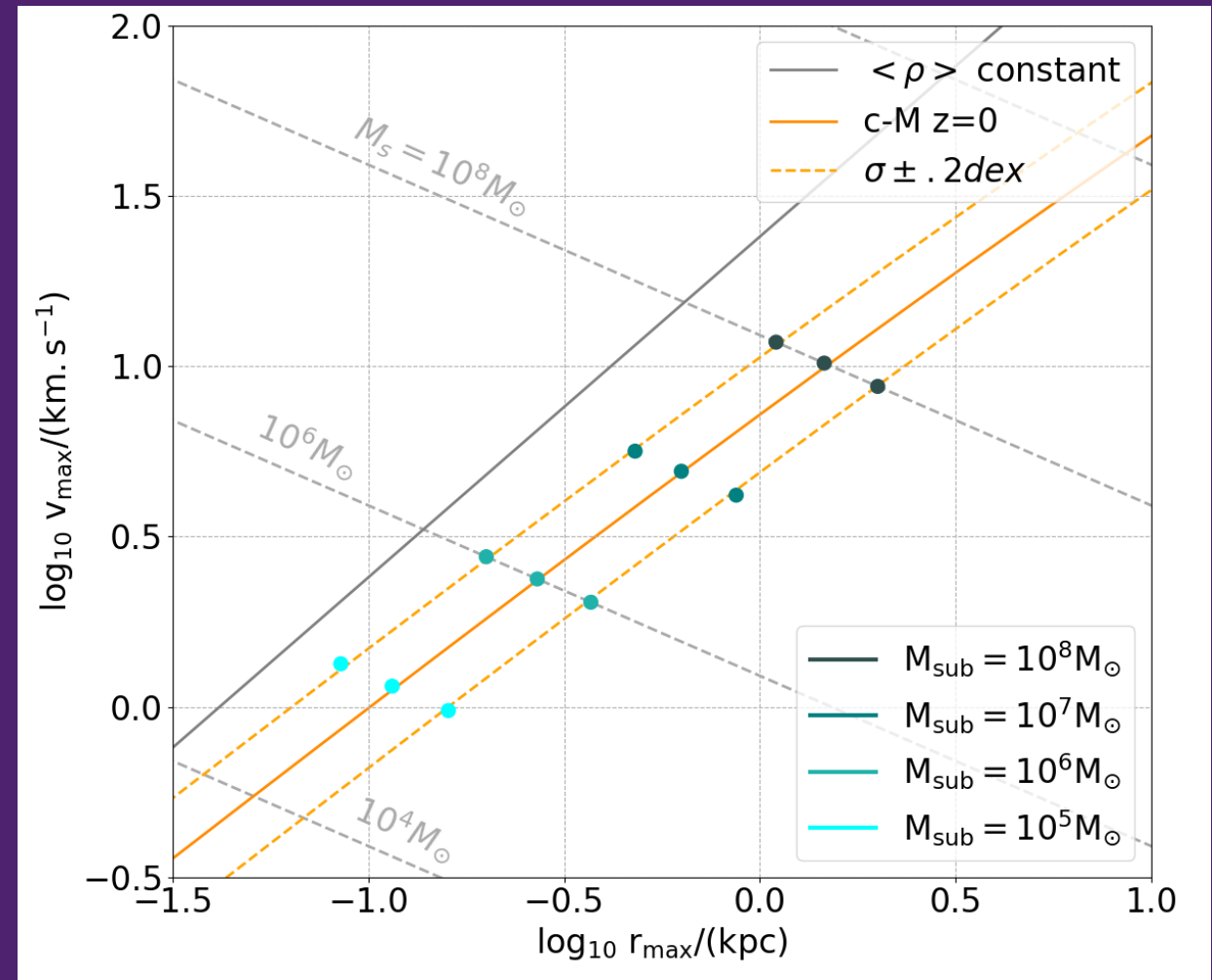


*Errani et al 2022*

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- Why ?
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- How ?
  - Progenitor GC
  - Subhalo models

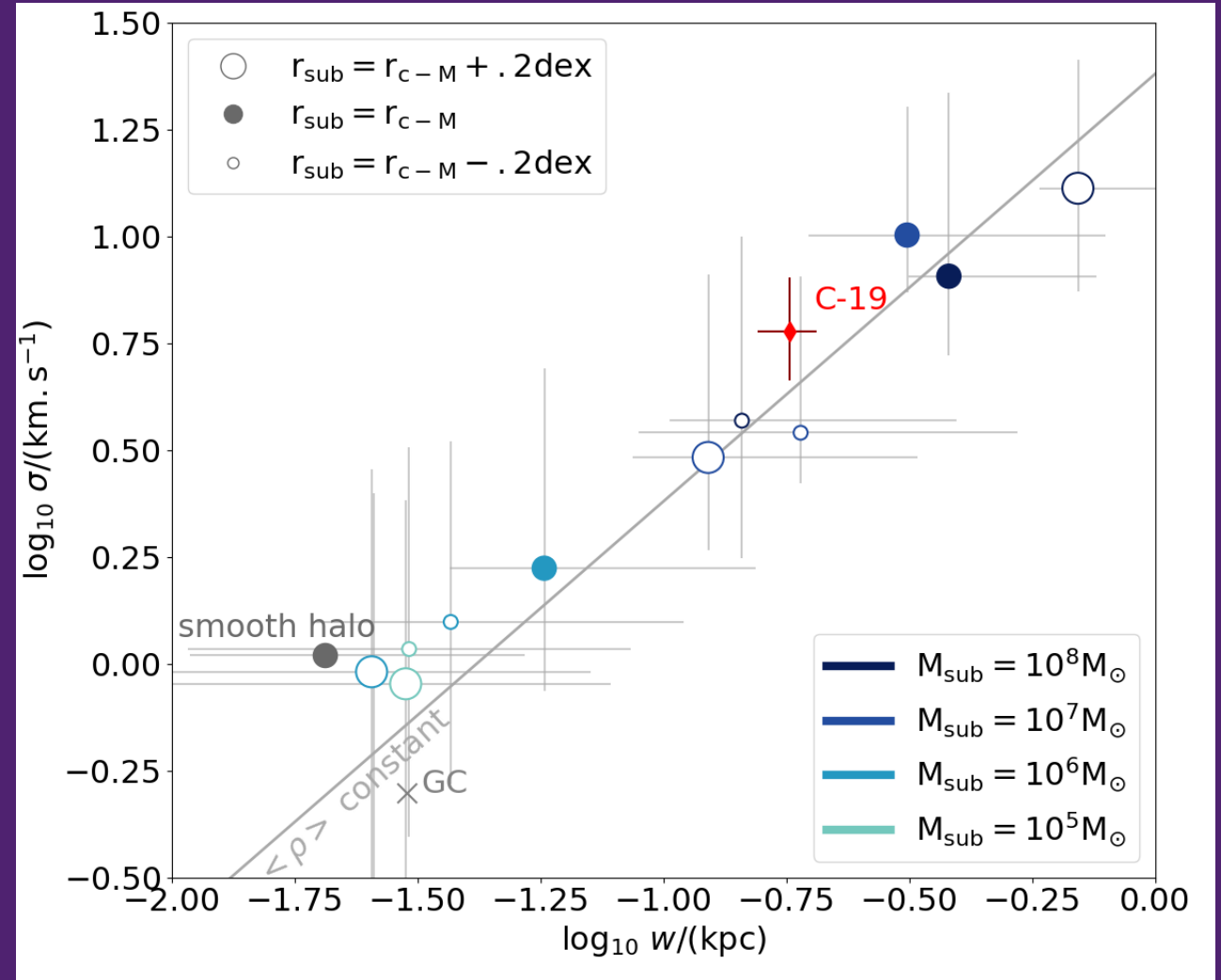


### III. Discussion – Application

#### ➤ Application to C-19

- Why ?
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- How ?
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#### ➤ C-19 heating!



### III. Discussion – Limitations

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#### ➤ Model limited by :

- C-19 projection effect
- Simplified Milky Way
- Halo mass function not taken into account
- Softening not consistent with NFW subhalos

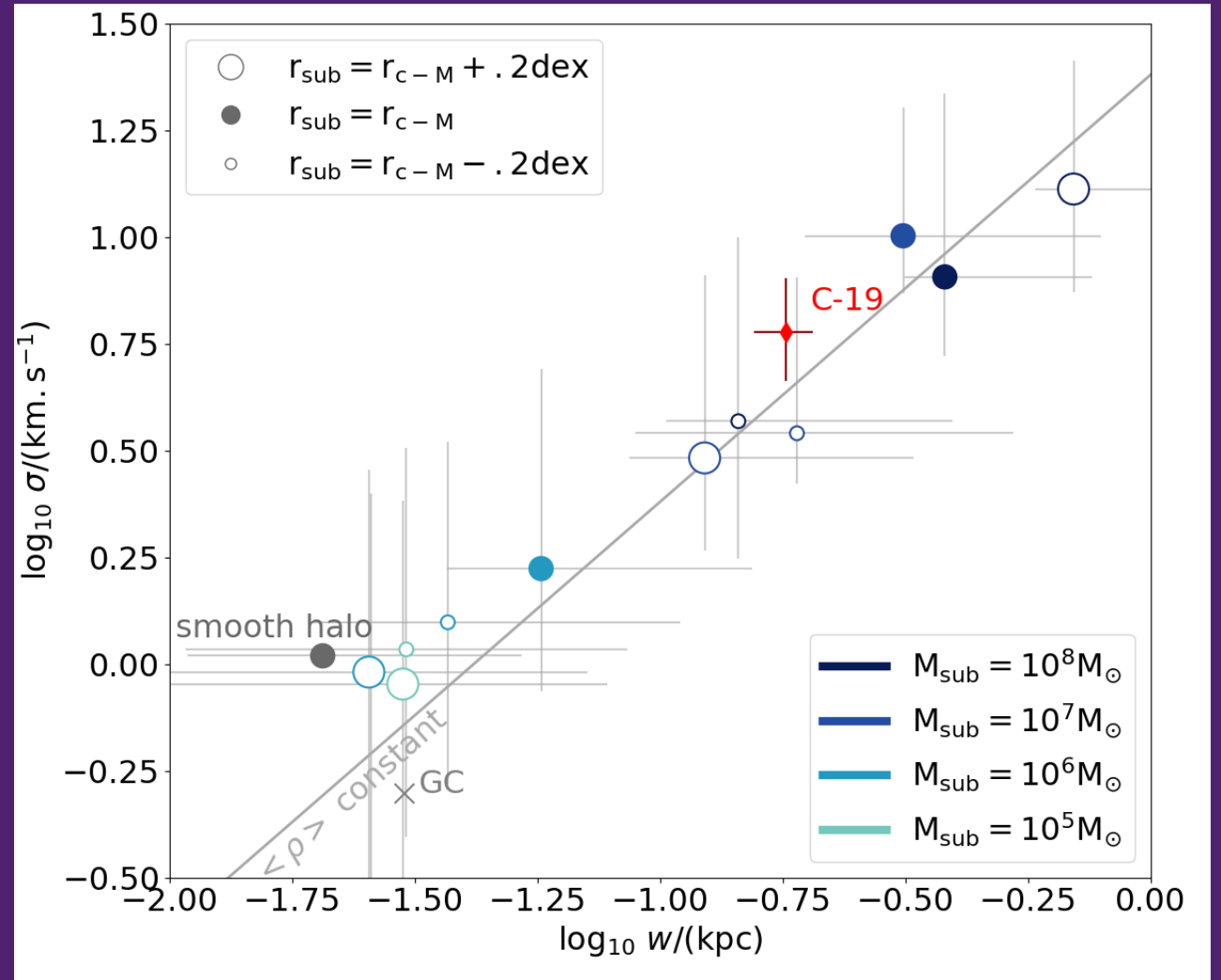


### III. Discussion – Conclusion

- Heating increases with :
  - Number of substructures
  - Mass of substructures
  - Density of substructures

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- Heating increases with :
  - Number of substructures
  - Mass of substructures
  - Density of substructures
- C-19 high dispersion :  
Possible! But...



# Annexes

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Observatoire **astronomique**

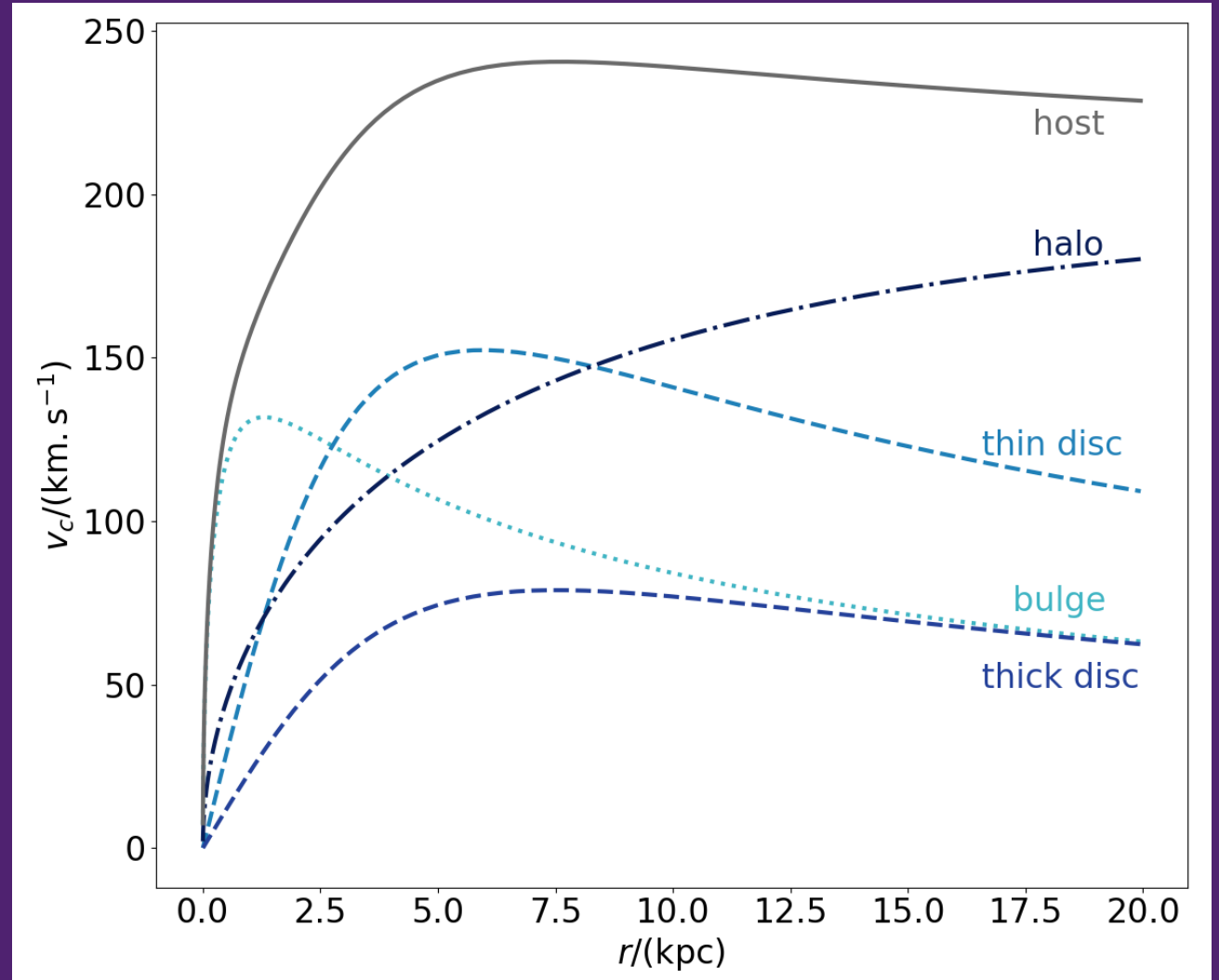
de Strasbourg | ObAs

# Milky Way

## ➤ Milky Way-like galaxy

- Bulge (Hernquist)
- Discs (Miyamoto-Nagai)
- Halo (Navarro NFW)

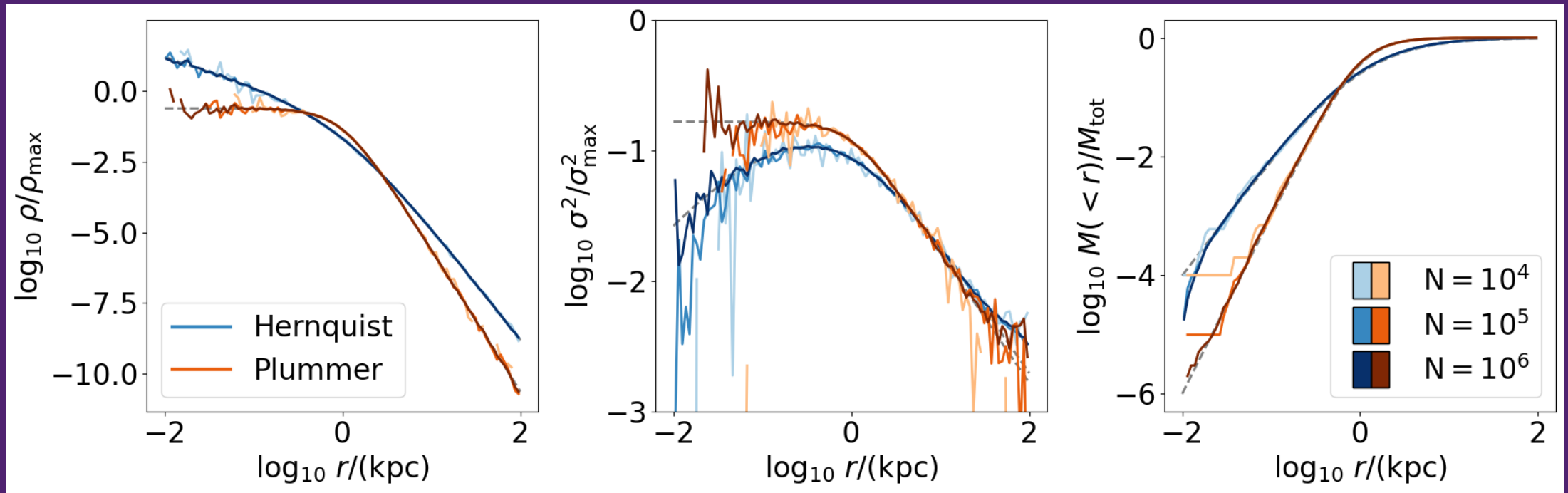
## ➤ Host Galaxy



# Stream progenitors

## ➤ Progenitor Profiles :

- $(\alpha, \beta, \gamma)$  density profiles      Hernquist (1, 4, 1)      Plummer (2, 5, 0)



# Stream progenitors

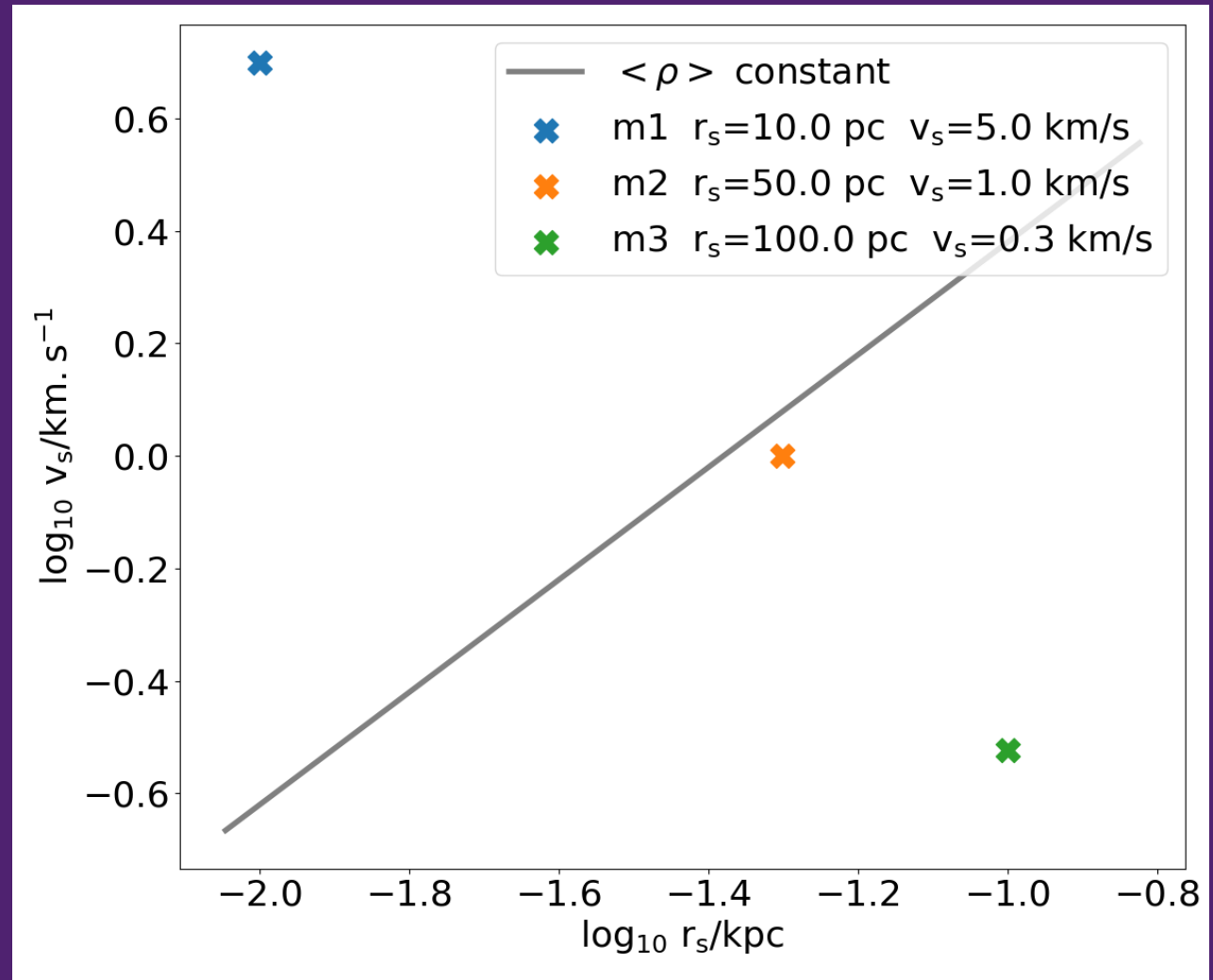
## ➤ Progenitors

- Globular Clusters (Plummer sphere)
- Disruption?

$$T_{Galaxy} = T_{Plummer}$$

$\propto$

$$\frac{r_{peri}}{v_c} = \frac{r_s}{v_s}$$

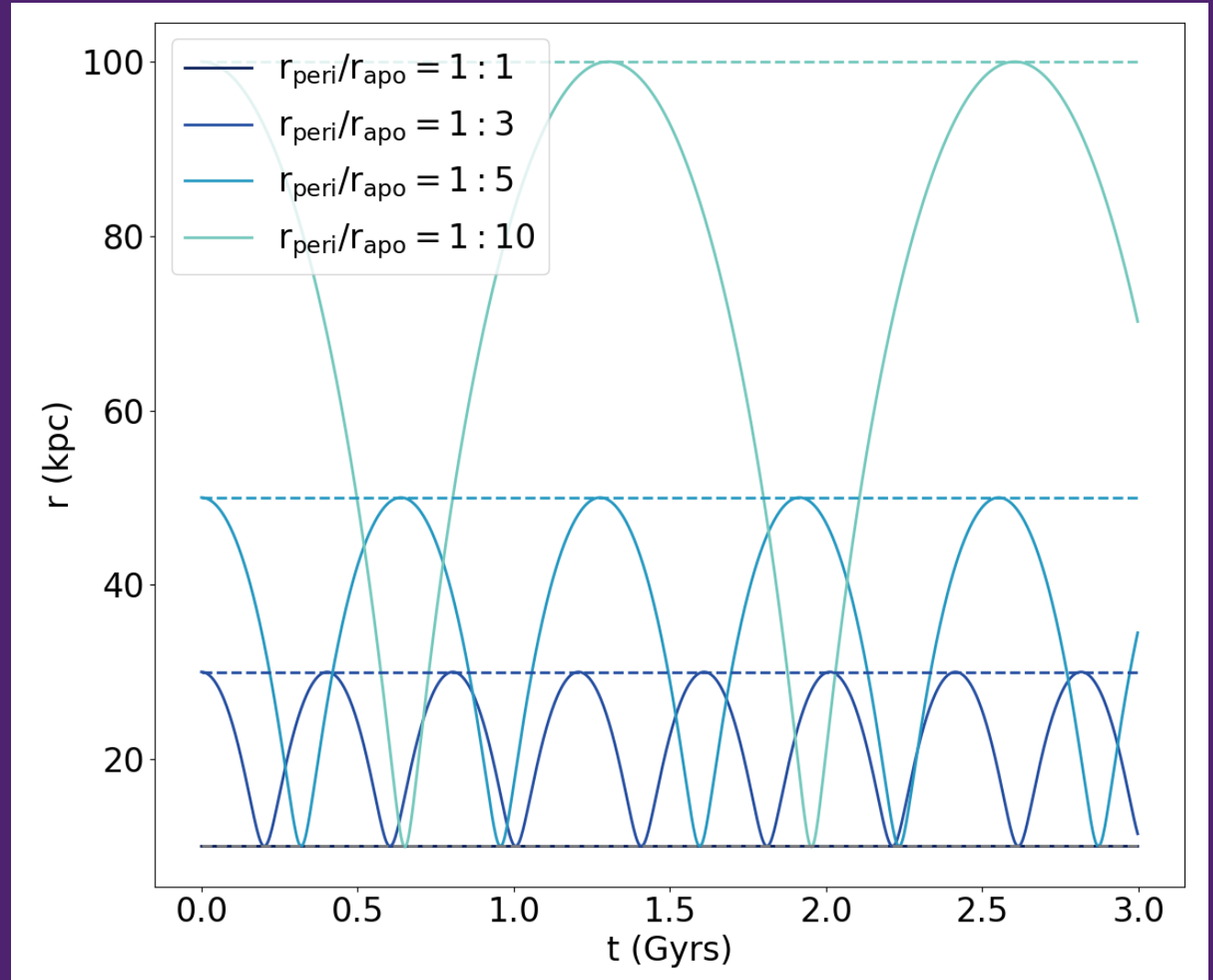


# Stream orbits

## ➤ Orbits :

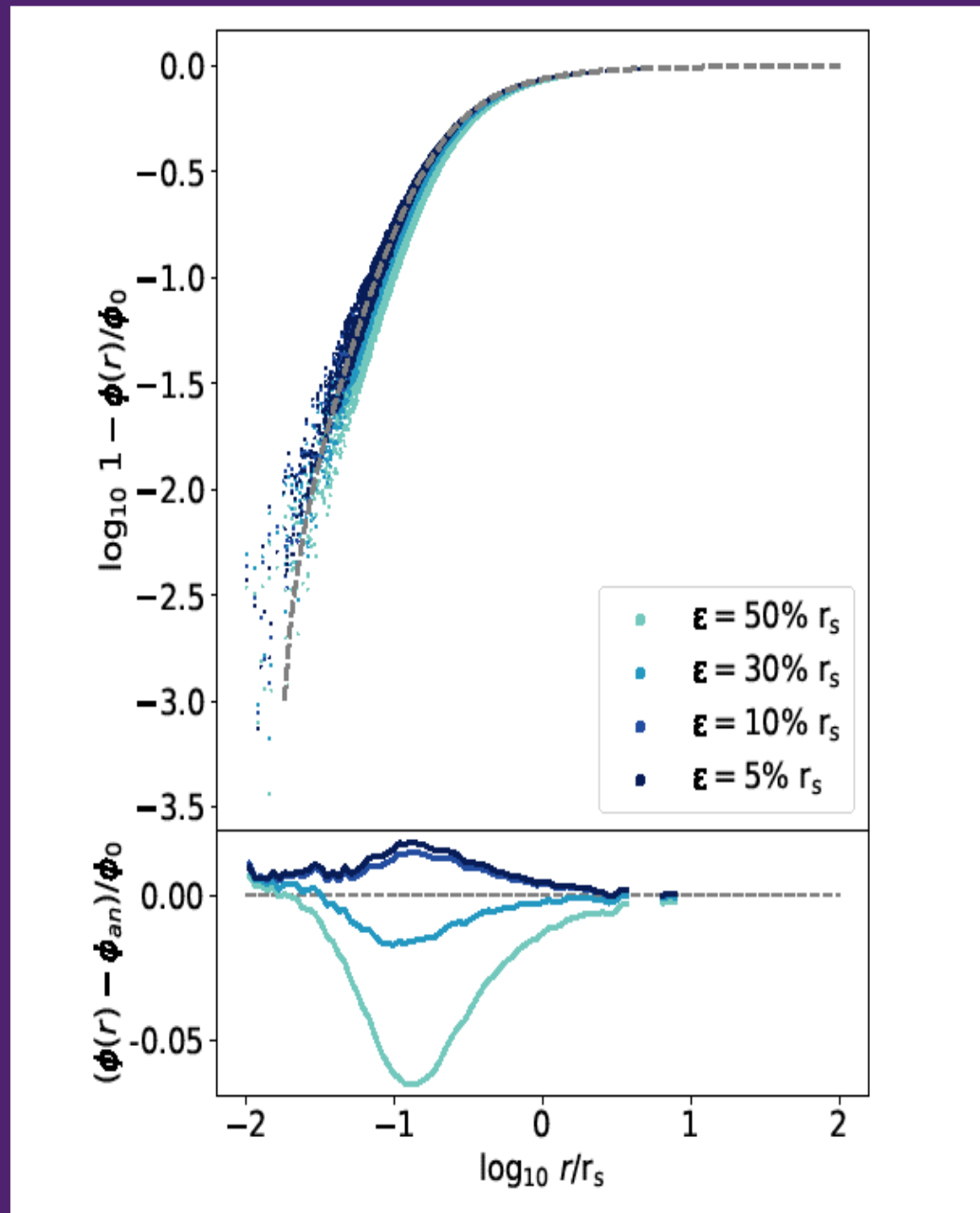
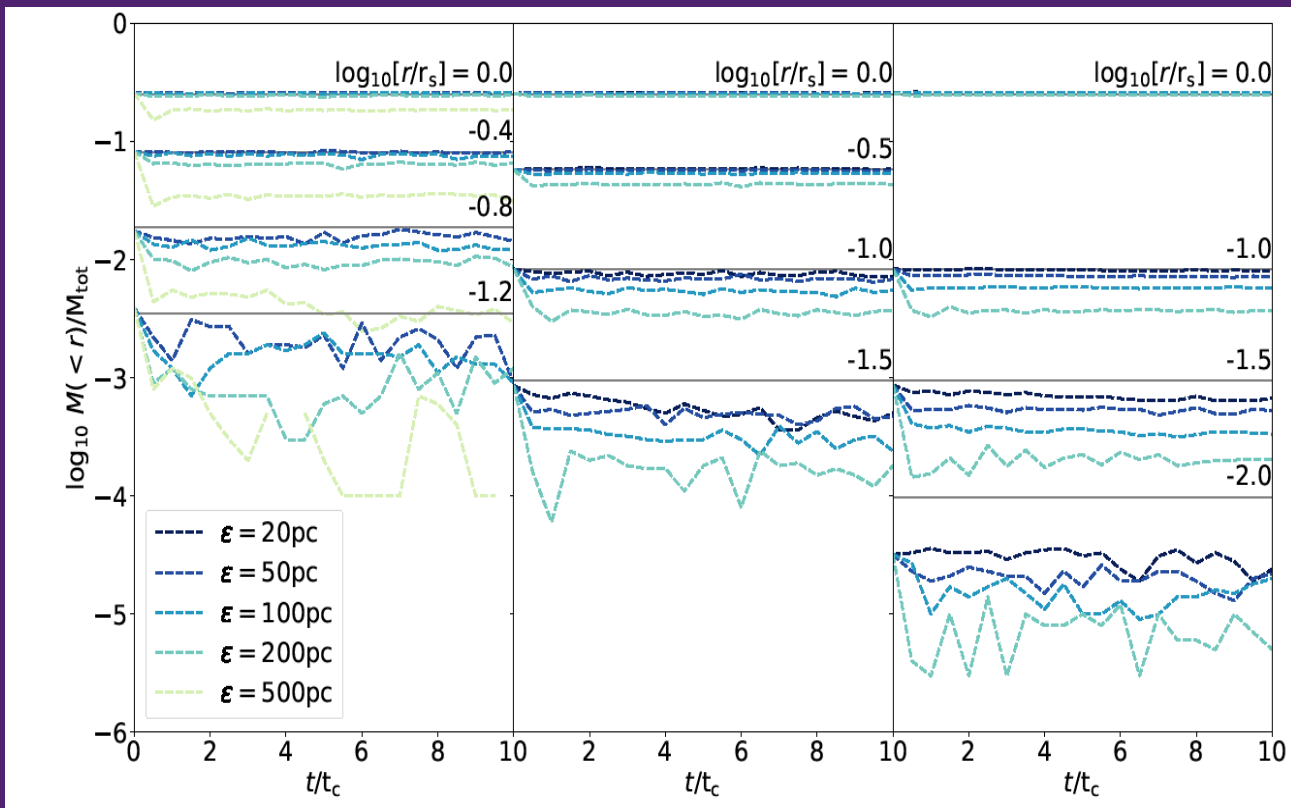
- Pericenter 10 kpc
- Apocenter 10 to 100 kpc

## ➤ 4 Orbits





# Stability check : Mass under r Gadget potential



# Number of substructures for mass of substructures

