Subhalos from the Hierarchical Bound-Tracing Code

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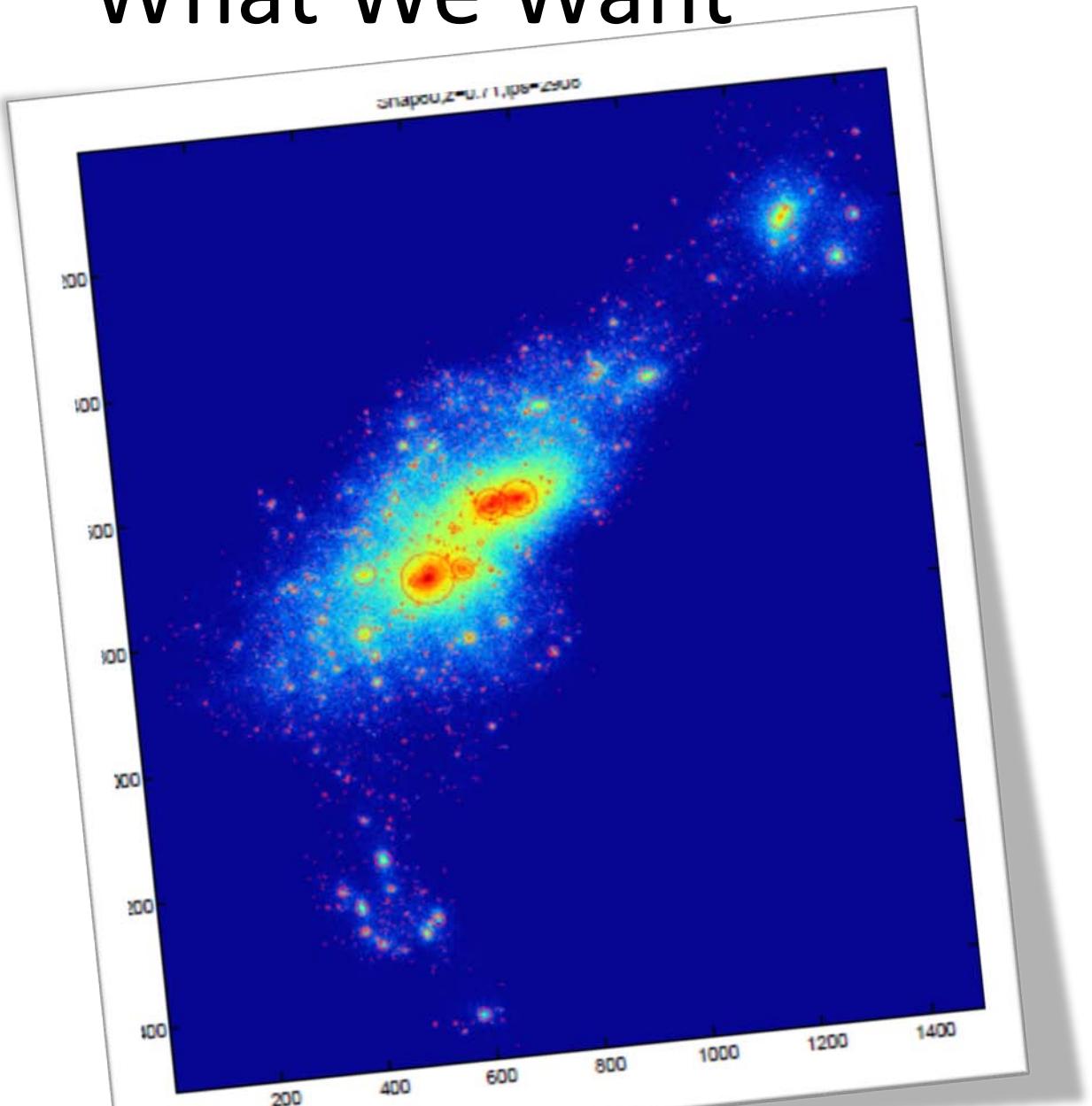
Outline

- Physics of subhalos
- What we do in HBT
- What's the subhalos like in HBT
- What you can get from HBT
- How to get them from HBT

I. Physics

What We Want

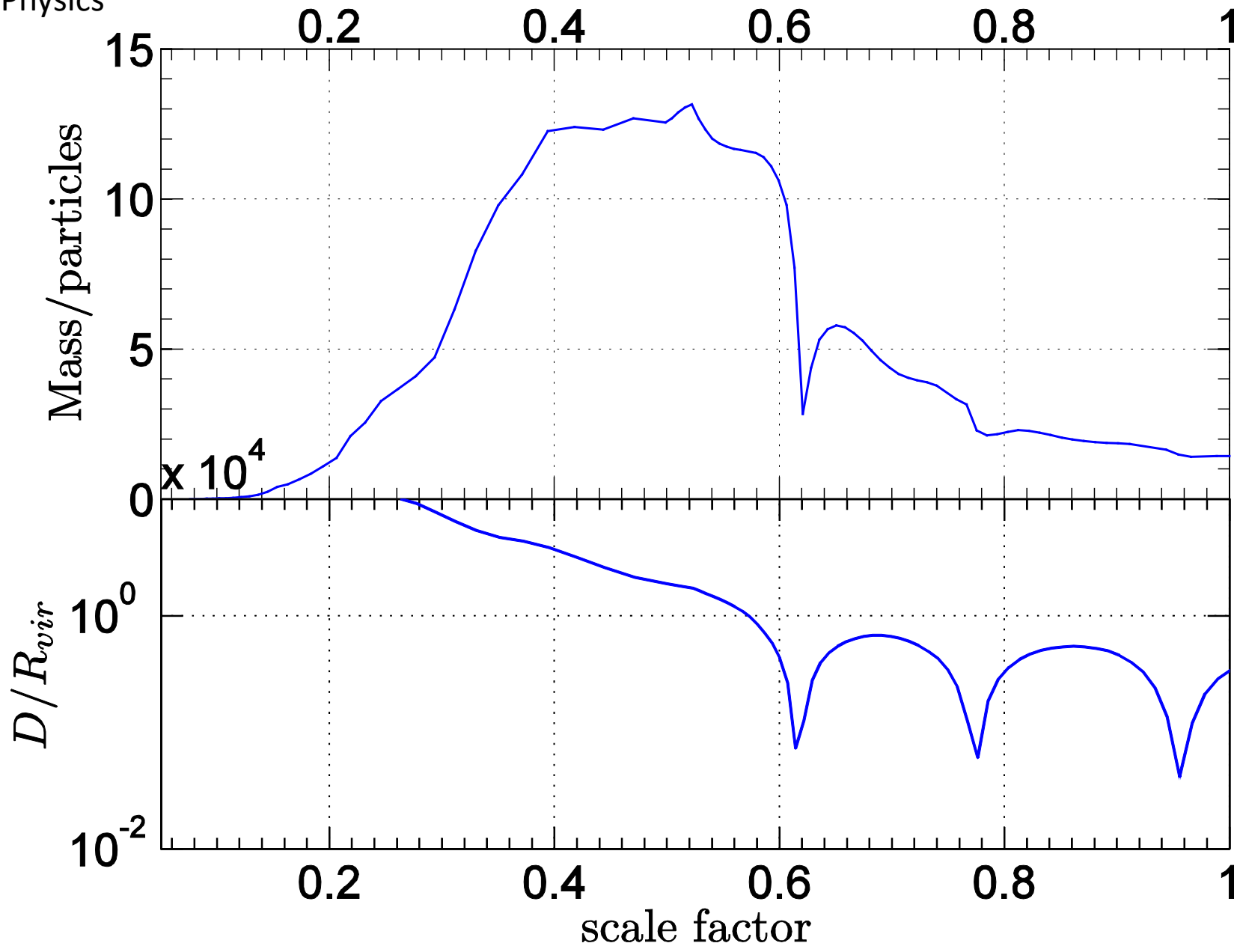


What is a subhalo

- 1. it is an overdense region inside a halo,which we call its host halo
- 2. it is self-bound so that it’s dynamical significant
- 3. it was a halo before it mergers into its current host halo

Life of subhalos

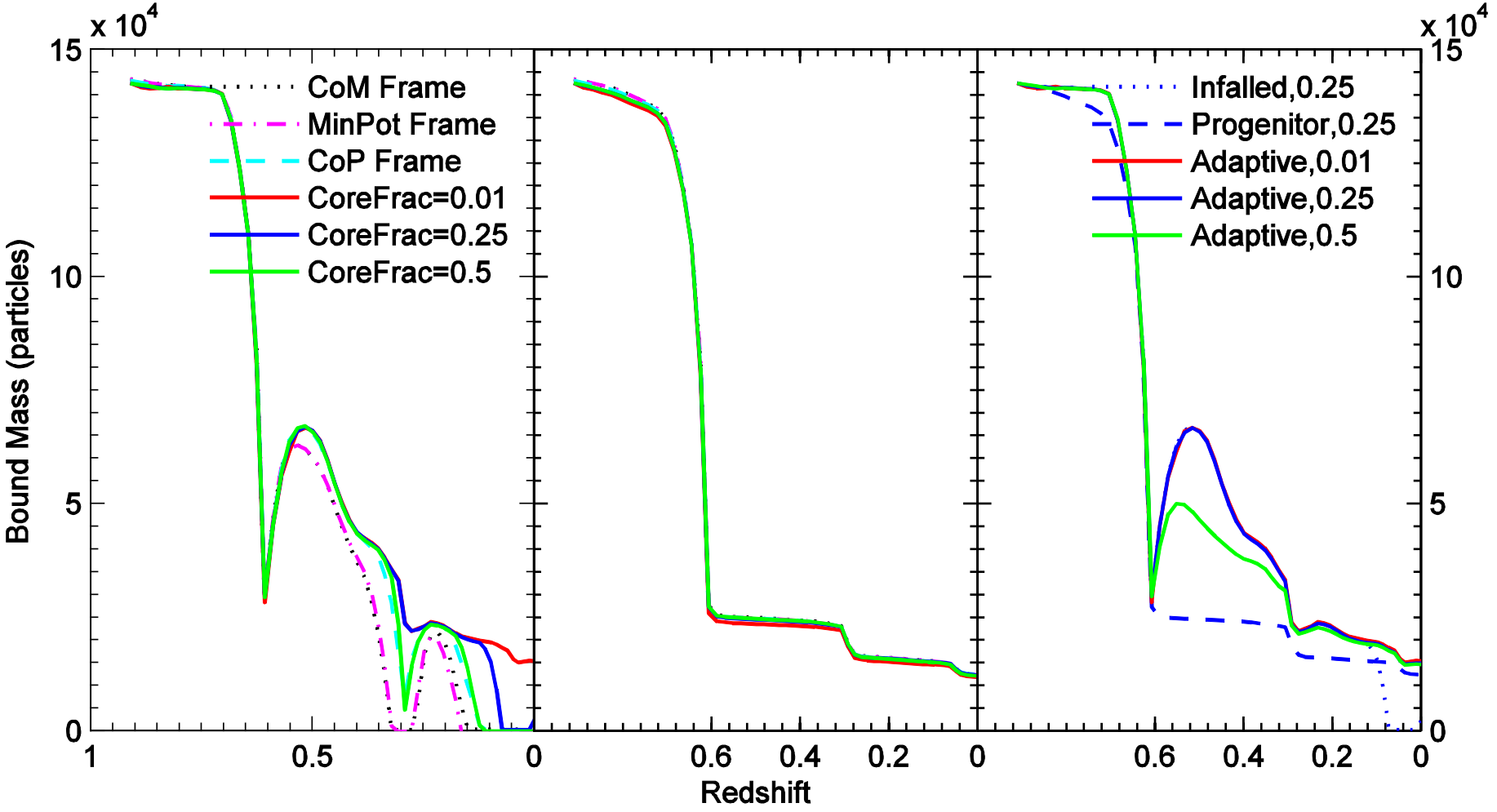
- birth: growth of density peak to above resolution; stripped out structure
- growth: accretion and merger in the halo stage
- decay: strip as satellite, tidal force and dynamical friction
- transition: merger
- secondary effect:
  - inner accretion/merger, within satellite tidal radius from sub-in-sub
  - local accretion, background capture: negligible.


0.2
0.4
0.6
0.8
1
15
10
5
0
Mass/particles
x 10^4
10^0
10^{-2}
D/R_{vir}
0.2
0.4
0.6
0.8
1
scale factor

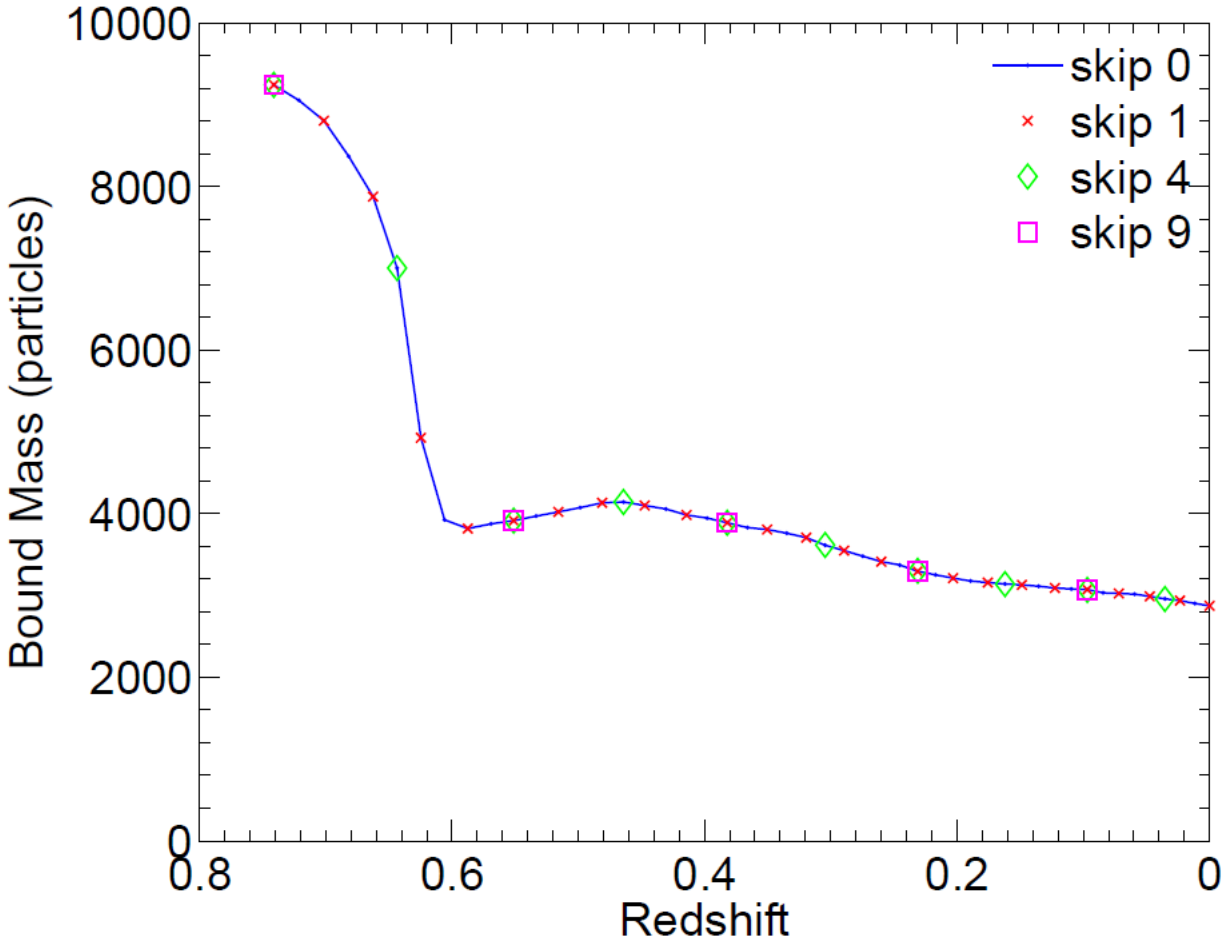
What we do in HBT

- Bound-Tracing
  - Surviving merged-in halo
    - Main sub:
      - biggest self-bound part of the FoF halo
      - can accrete from within its FoF
    - Satellite sub:
      - lose mass to the main sub under stripping or merging
      - Hierarchical merging →Historical Sub in Sub
      - Subhalos can accrete from their sub-in-subs: sat-sat merger
      - Local accretion: omittable
  - Self-bound (E=T+U<0)
    - Satellites: re-accretion of lost particles allowed
  - Exotic staff
    - Splinters
    - Quasi-halos

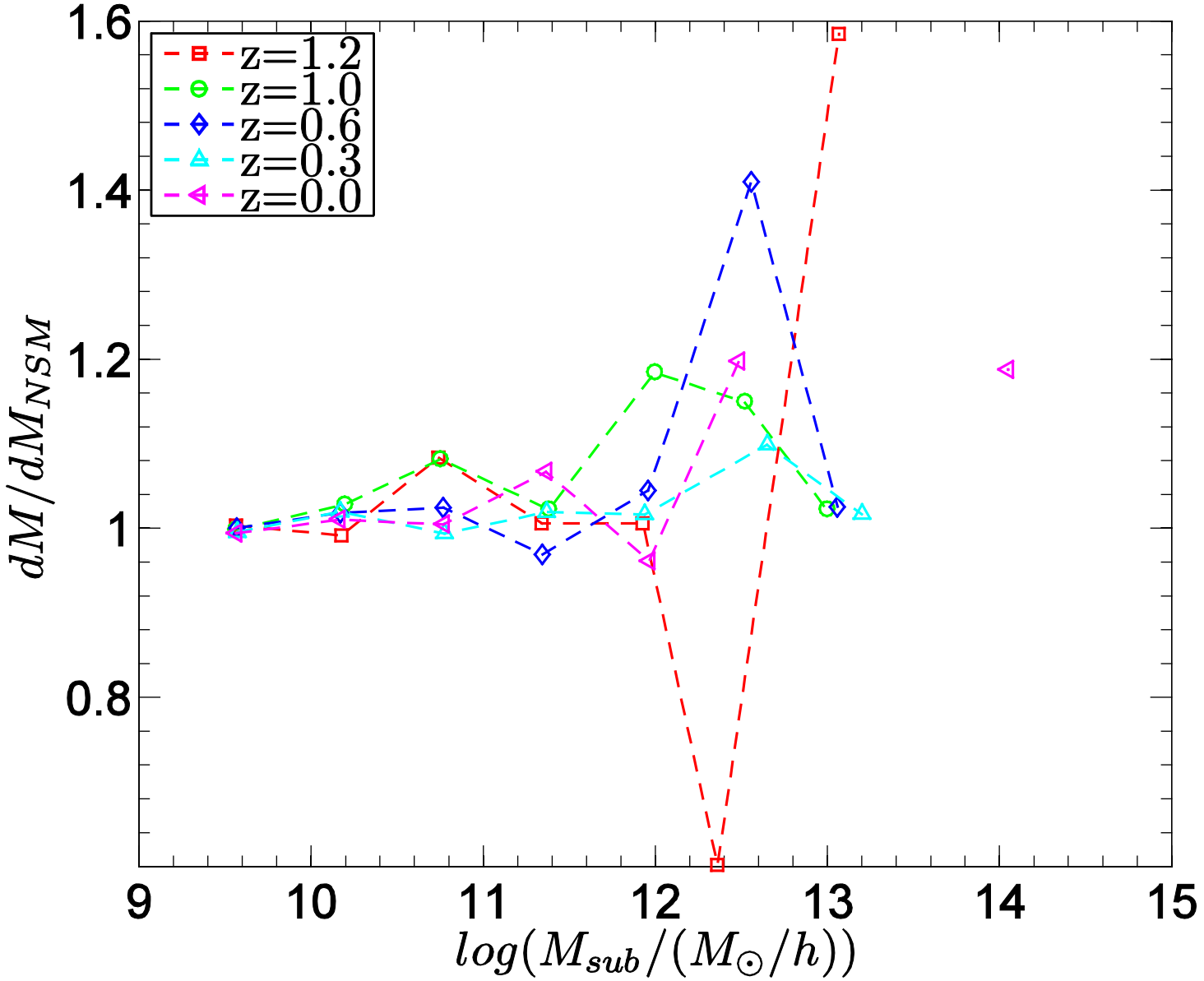
To trace safely: robustness and reaccretion



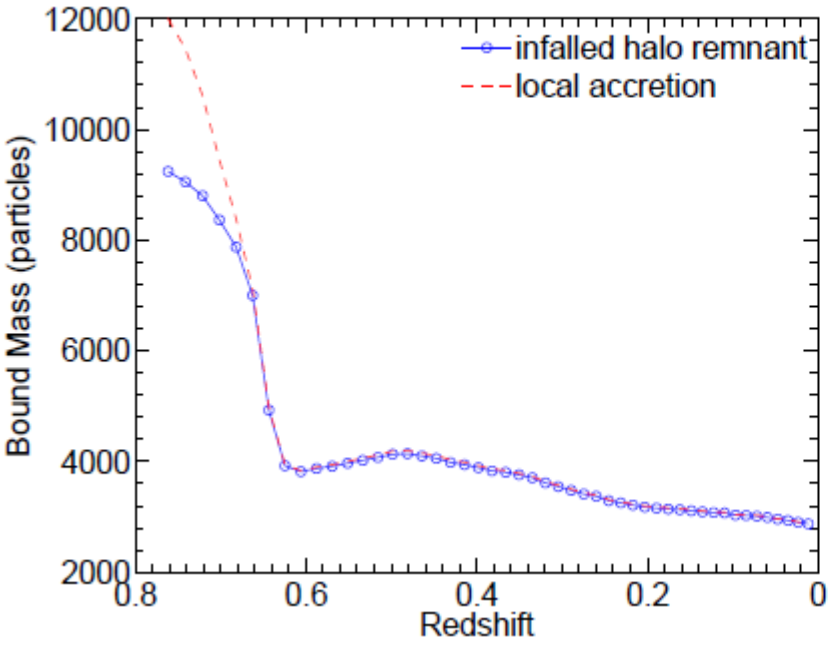
To trace confidently: Time resolution requirement

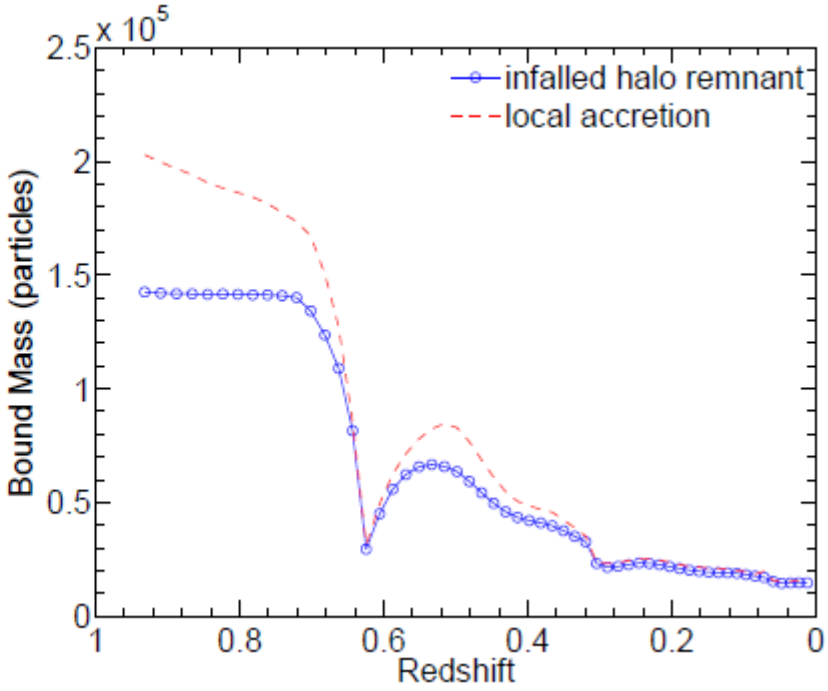


Secondary effect: Satellite Accretion



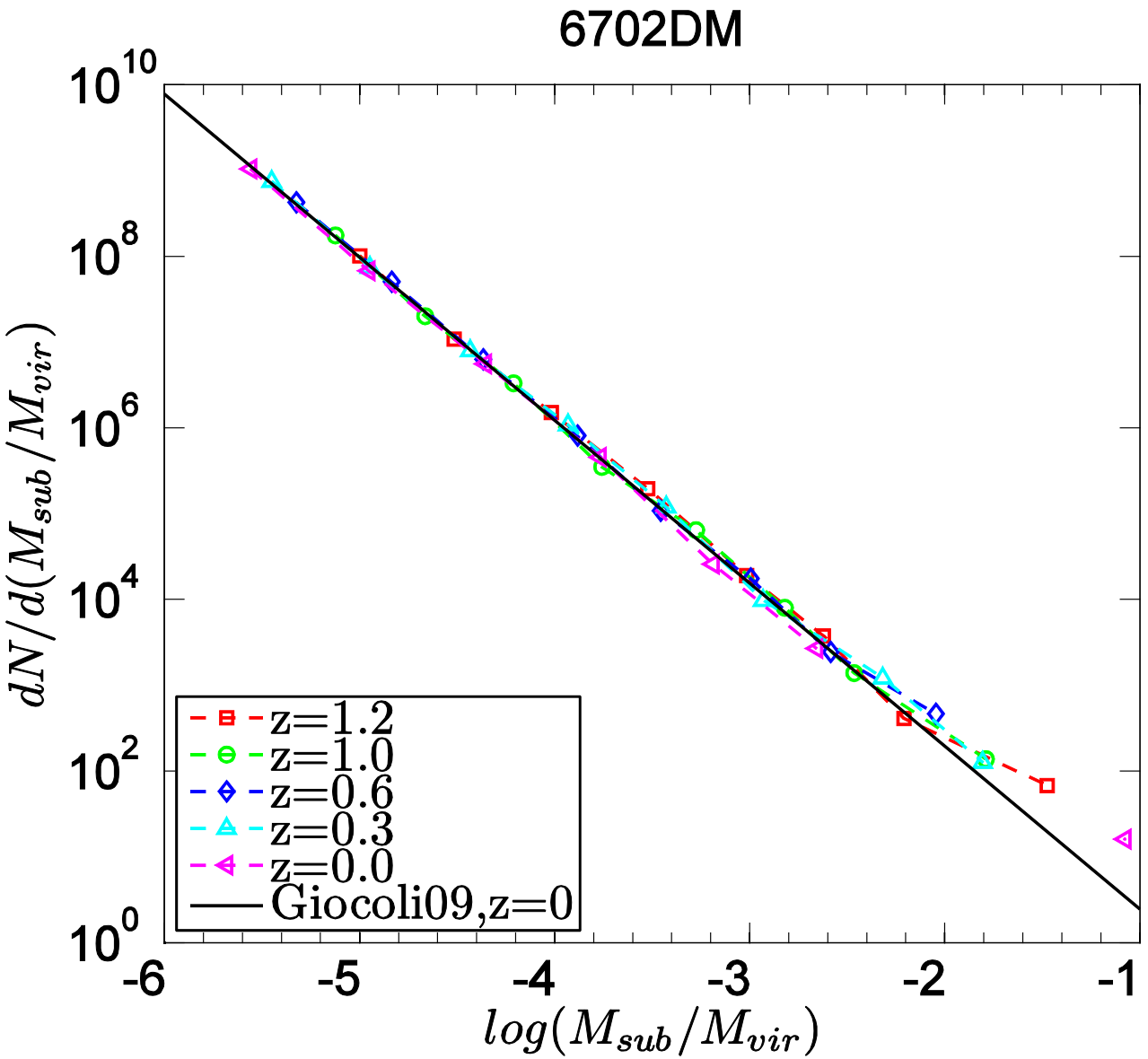
Secondary effect: Local Accretion



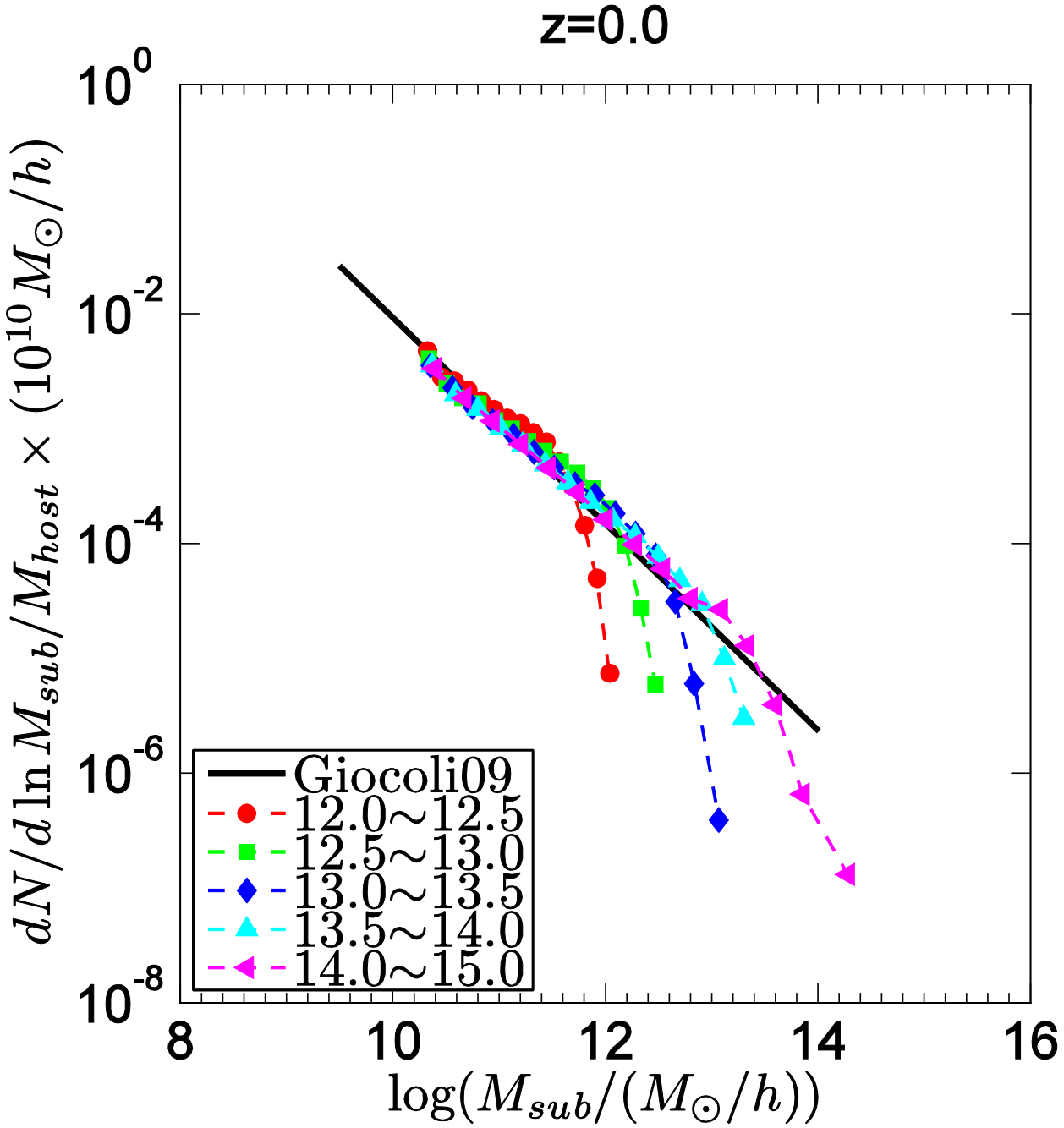


III. Result

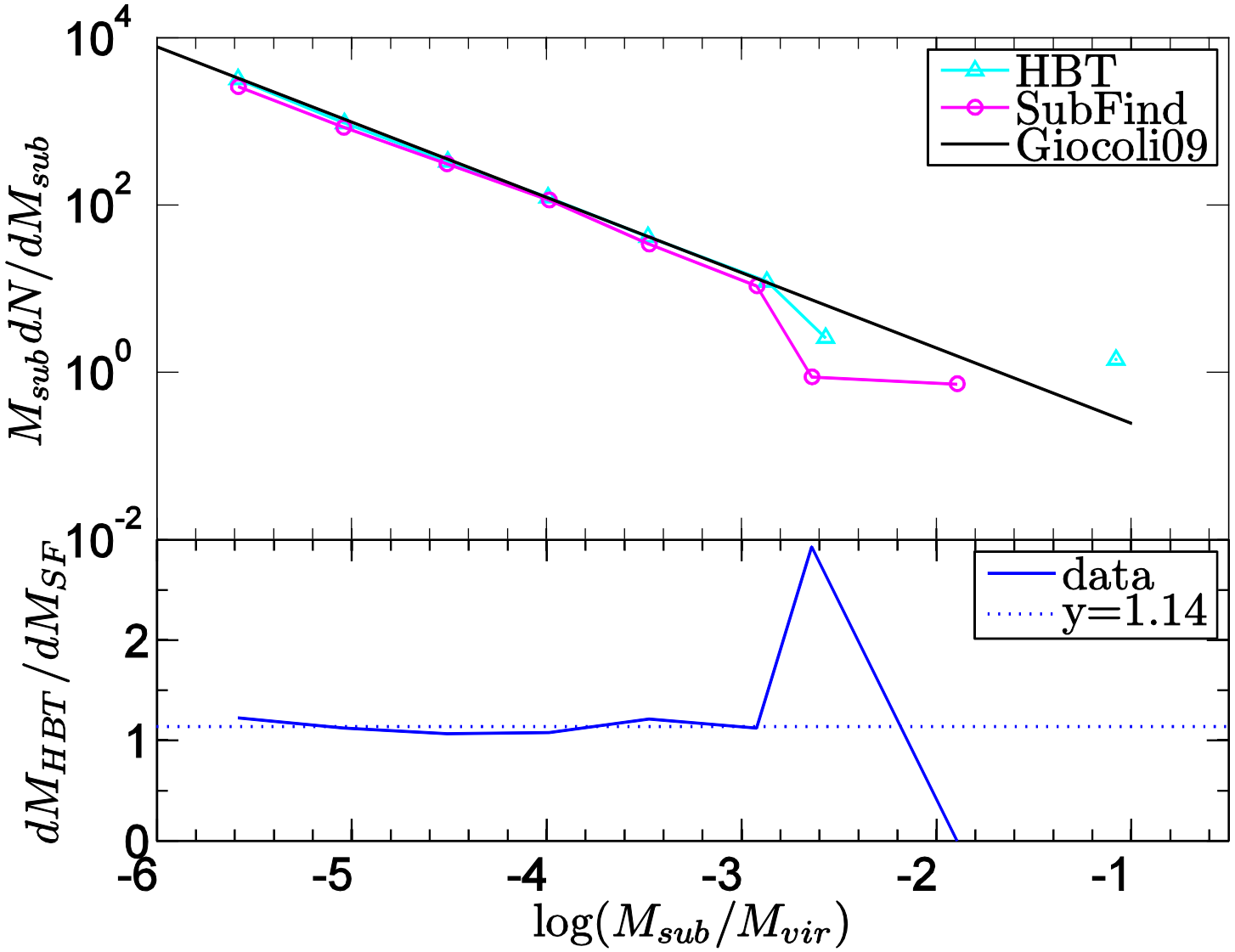
What we found in HBT



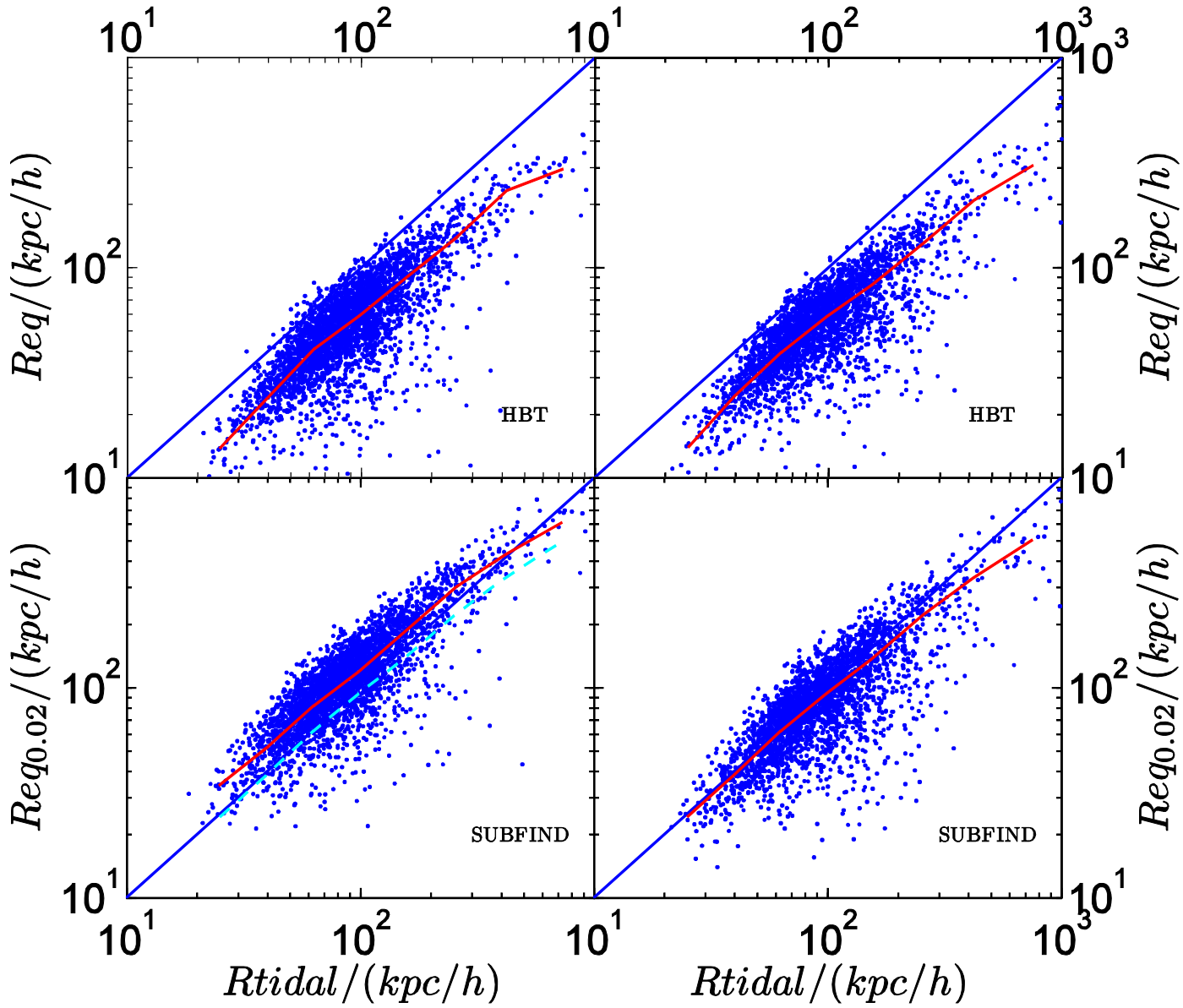
III. Result


z=0.0
10^0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
$dN/d\ln M_{sub}/M_{host} \times (10^{10} M_\odot/h)$
8
10
12
14
16
$\log(M_{sub}/(M_\odot/h))$
Giocoli09
12.0~12.5
12.5~13.0
13.0~13.5
13.5~14.0
14.0~15.0

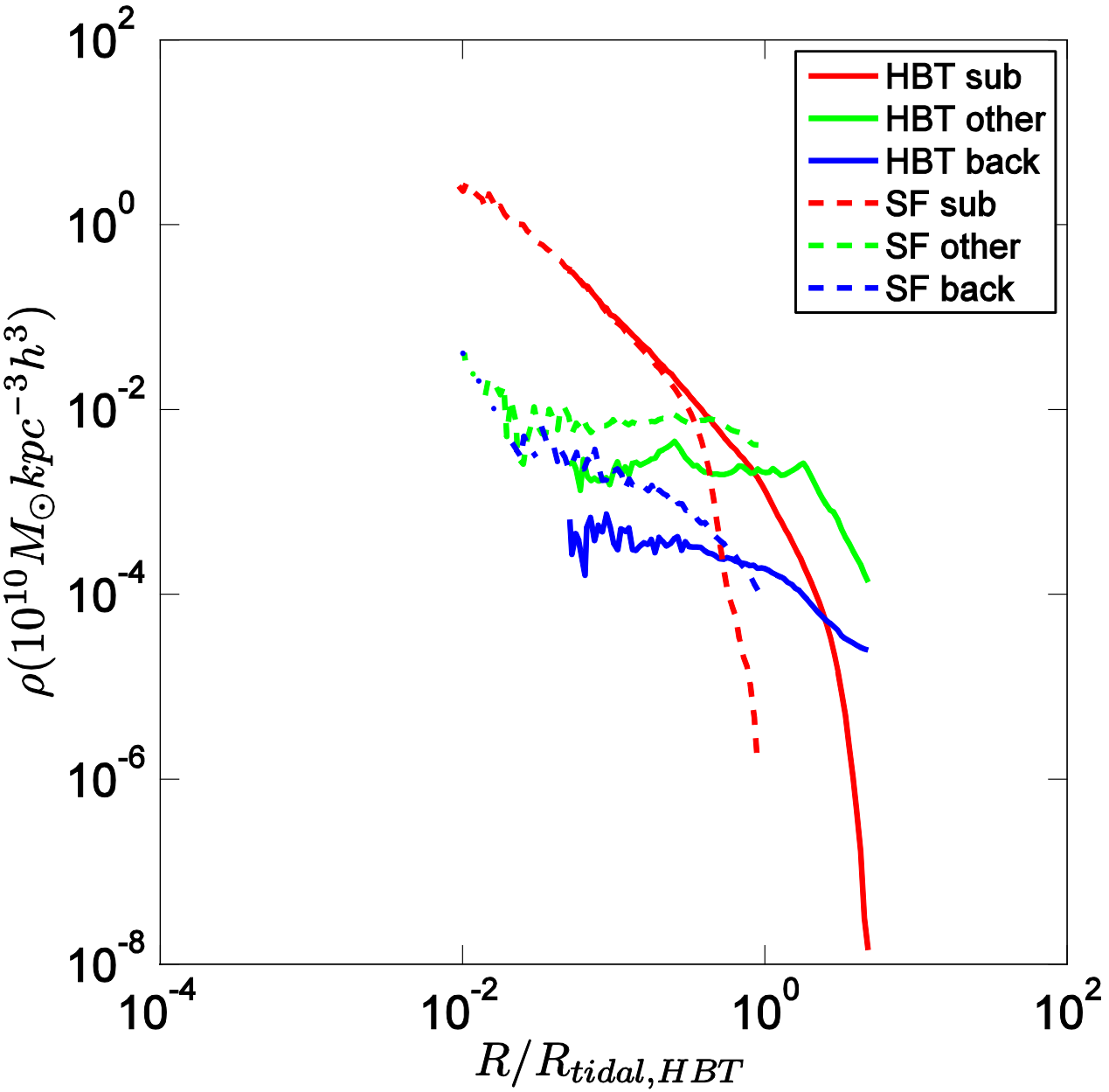
Comparison to SubFind



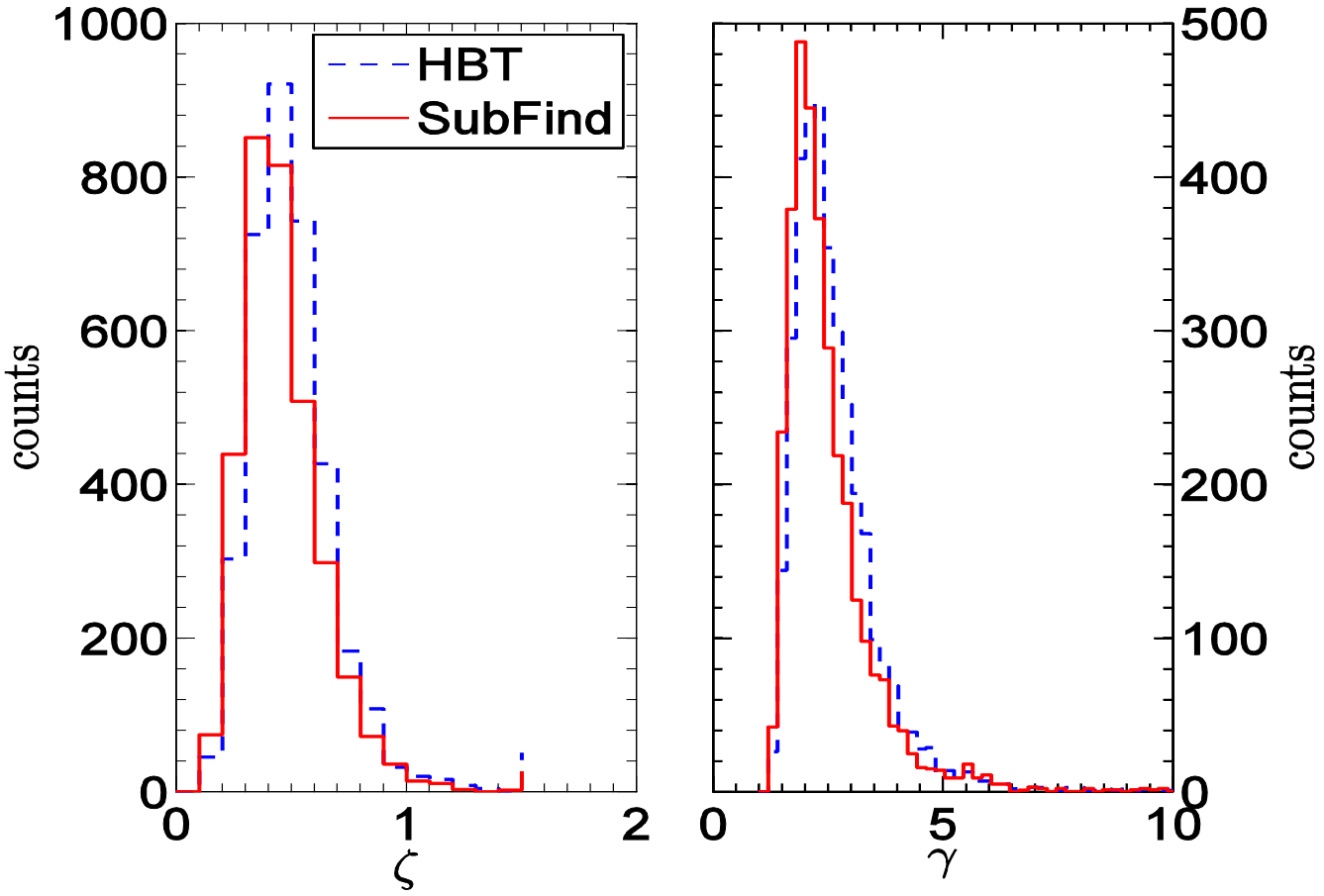
III. Result


HBT
HBT
SUBFIND
SUBFIND
$Req/(kpc/h)$
$Req_{0.02}/(kpc/h)$
$Rtidal/(kpc/h)$
$Rtidal/(kpc/h)$

III. Result


HBT sub
HBT other
HBT back
SF sub
SF other
SF back
10^2
10^0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-4}
10^{-2}
10^0
10^2
$\rho(10^{10}M_\odot kpc^{-3}h^3)$
$R/R_{tidal,HBT}$

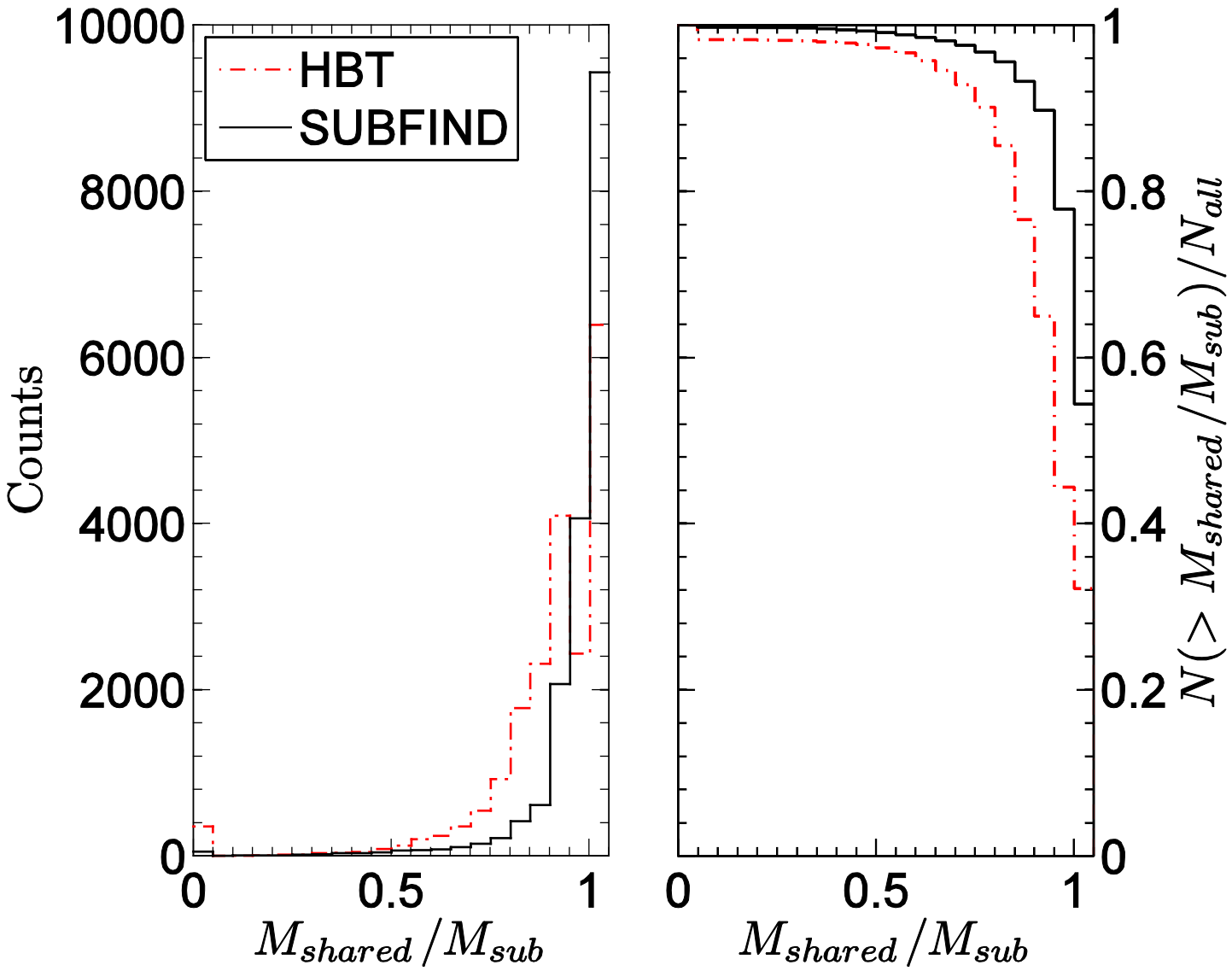
III. Result



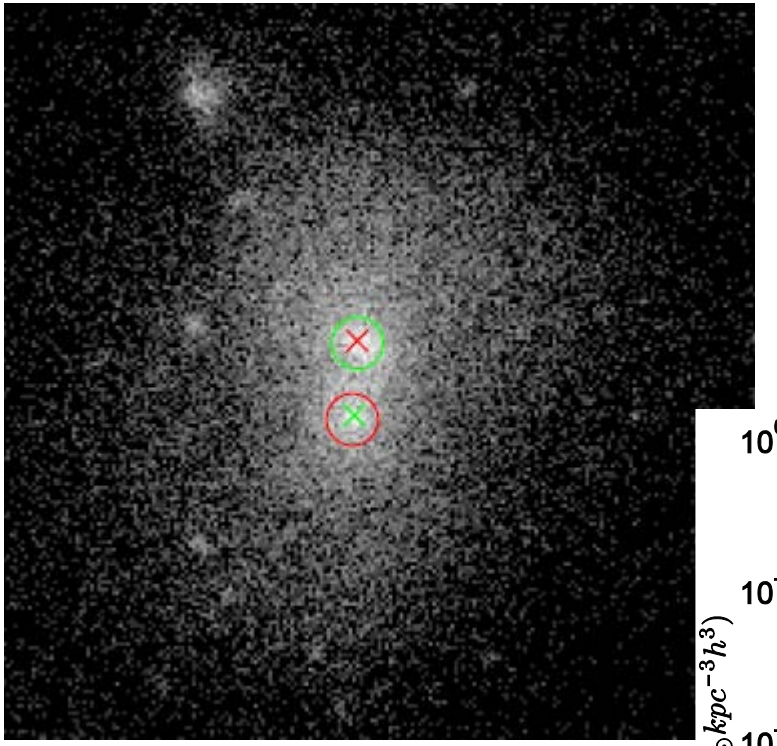
$$I_{ij} = \sum_{p \in A} (x_{i,p} - x_{i,0})(x_{j,p} - x_{j,0})$$

$$\zeta = \frac{\sqrt{\frac{1}{2}\sum_{i=1}^{3}(I_{ii} - \bar{I})^2}}{\bar{I}} \qquad \gamma = \frac{\max(I_{11}, I_{22}, I_{33})}{\min(I_{11}, I_{22}, I_{33})}$$

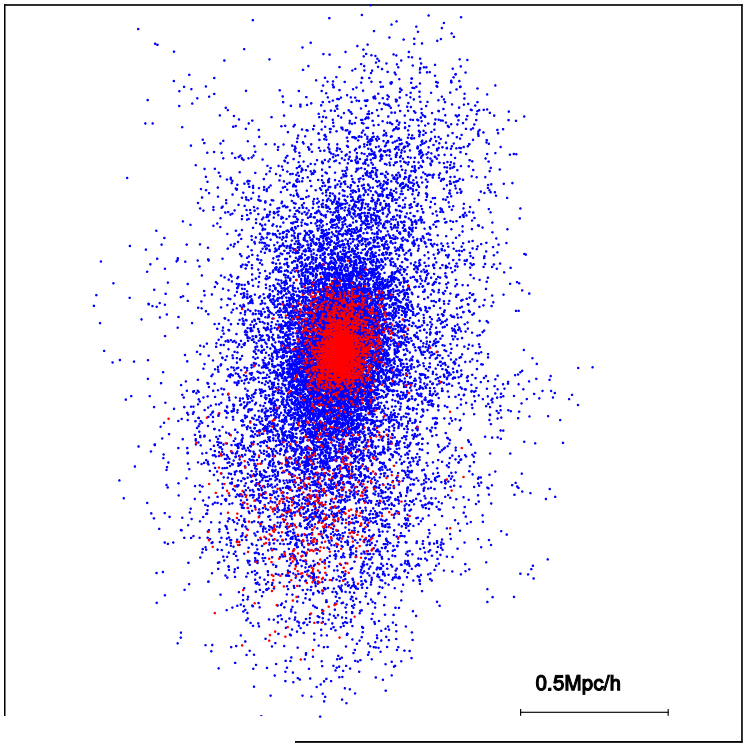
III. Result


HBT
SUBFIND
Counts
10000
8000
6000
4000
2000
0
0
0.5
1
M_{shared}/M_{sub}
1
0.8
0.6
0.4
0.2
0
$N(>M_{shared}/M_{sub})/N_{all}$

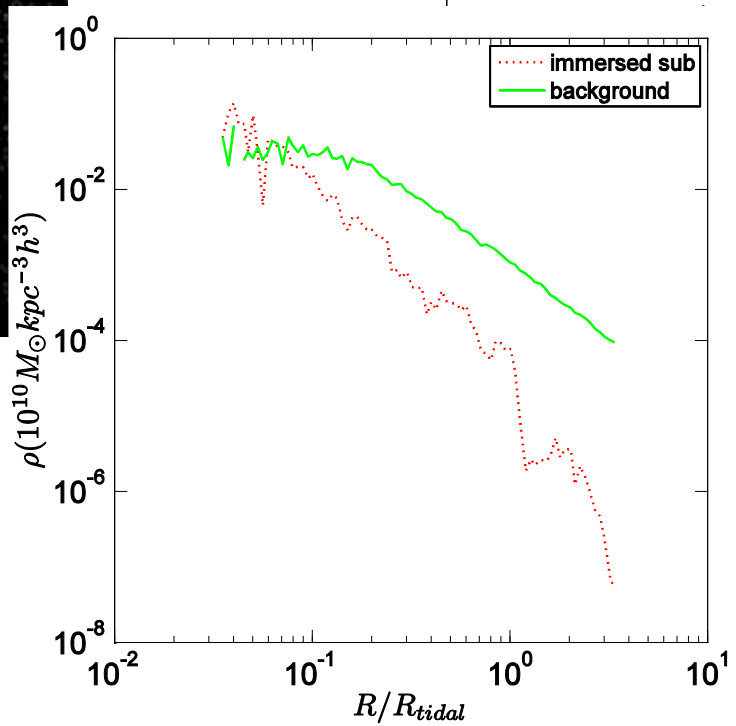
Multiple match betwe
SubFind



Who is master?



One or Two?



Stop hiding!

Summary

- Bound-Tracing
  - Surviving merged-in halo
    - Main sub:
    - Satellite sub:
      - lose mass to the main sub under stripping or merging
      - can accrete from their sub-in-subs: sat-sat merger
      - Re-accretion of lost particles allowed
  - Self-bound ($E=T+U<0$)
- Merit:
  - Constructing merger tree together with finding subhalos, less ambiguity
  - Remain good resolution in high density region, avoid over-truncation, bigger satellites than SUBFIND (15% in mass and 20%~30% in size)
  - No need for density interpolation and spatial searching, thus faster

What you can get from HBT

- subhalo catalogue:
  - particles sorted with energy
- merger hierarchy
- progenitor-descendent link, two-way
- Properties already have:....
- Additional properties:
  - halo prof, param
  - subhalo prof, size, shape
  - Evolution catalogue:node entries; parameters

How you can get them from HBT

- C library
  - Simulation/Halo IO
  - Subhalo IO
- Fortran module
  - Subhalo routines
- Document:
  - paper
  - readme

Practice

- Directory structure
- Data structure
- Functions and Examples