How to Zoom: Lagrange volumes and Other Halo Properties

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Galaxy Simulation Comparison Project Workshop

How to do a zoom (zoom-in/multimass/multiresolution/nested) simulation

Pipeline

1. Choose parameters: z_{ini}, resolution, cosmology, etc
2. Run dark matter only simulation
3. Identify the desired halo to zoom
4. Calculate the Lagrange volume region to re-simulate
5. Create ICs
6. Run zoom-in simulation. Check for contamination

How to do a zoom (zoom-in/multimass/multiresolution/nested) simulation

Using MUSIC (Hahn & Abel 2011)

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Lagrange volume definitions?

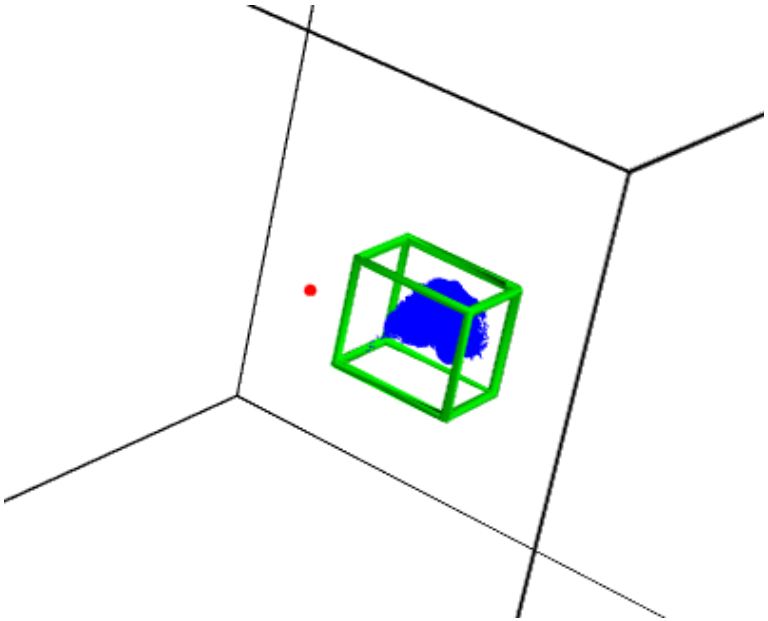
How do Lagrange volumes correlate with other properties?

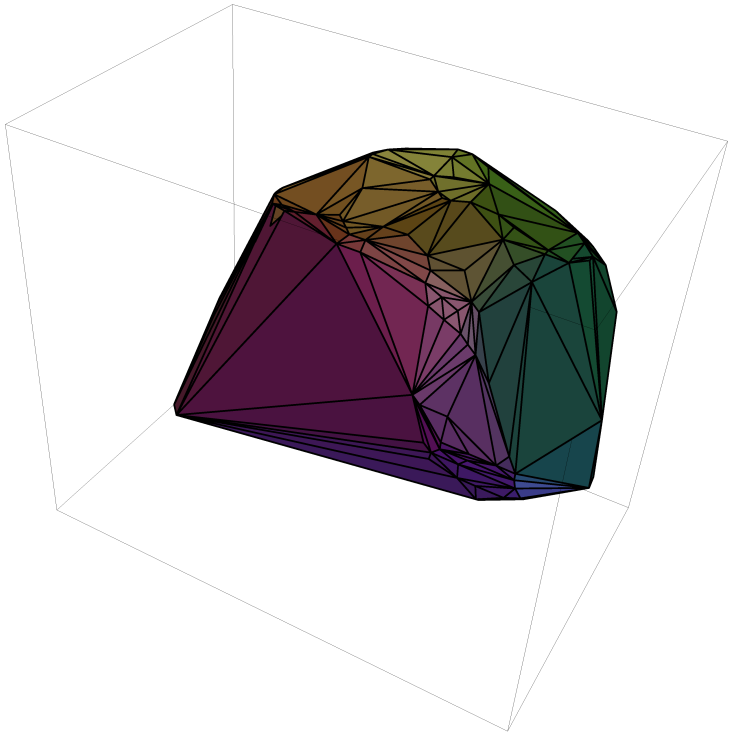
Improve method to guarantee no contamination?

How does contamination really affect the halos?

Lagrange volume Definitions

- Which particles do you trace back to z_{ini}? $N \times r_{vir}$, mainbranch(z), tree(z), fixed size, etc
- How do you define the volume at z_{ini}? Convex hull, Cuboid, Sphere, etc





Part I: Full box simulations

Simulations

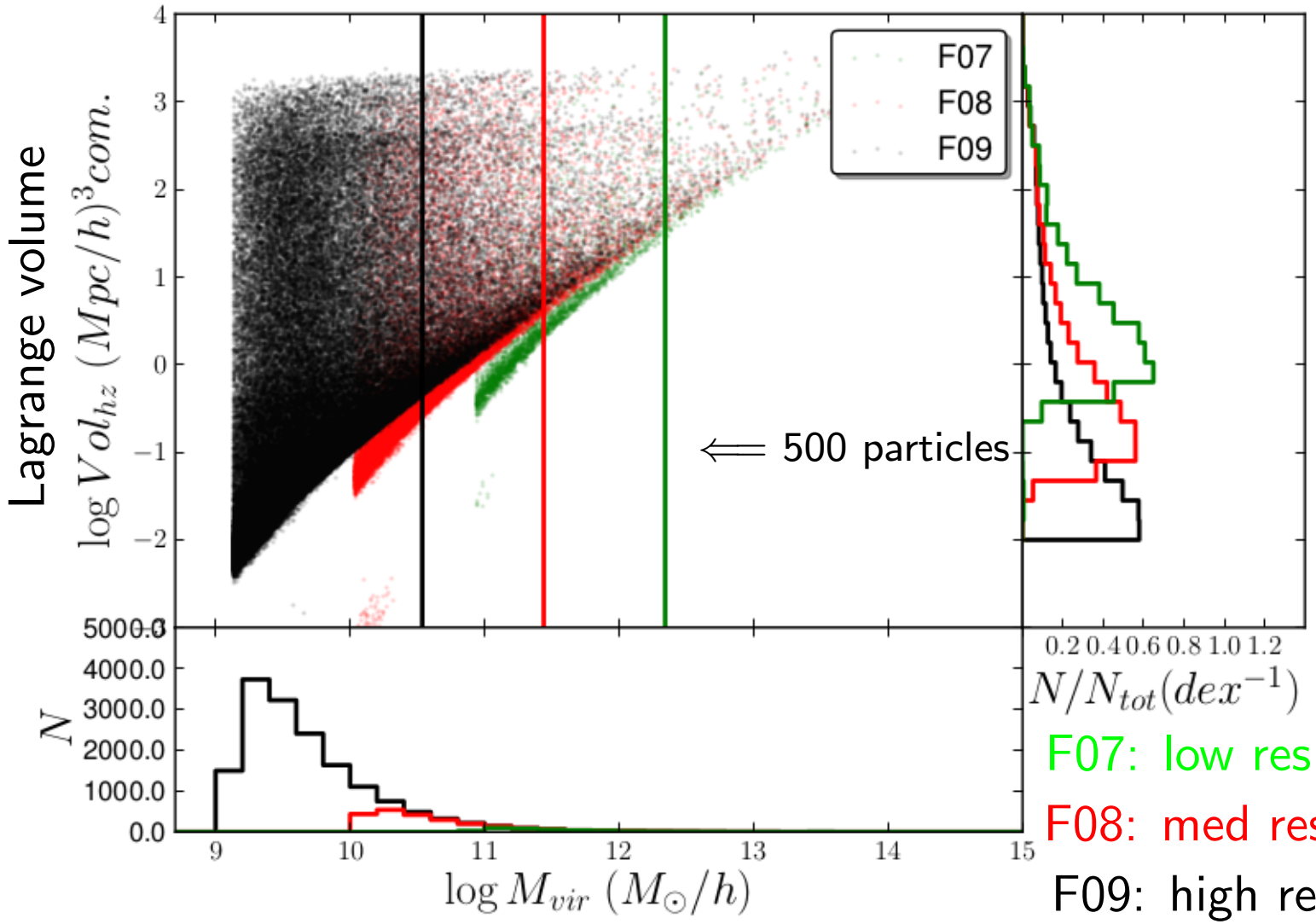
- resolution: 128^3, 256^3, 512^3
- L_{box} : $5, 10, 25, 50, 150, 650, 900$ Mpc/h
- z_{ini}
- codes: `GADGET` and `ENZO`
- hydro: adiabatic test runs

Properties analysis: AMIGA HALO FINDER (`AHF`;Knollmann & Knebe 2009)

- M_{vir}, V_{max}, λ, shape, T, $conc.$, a_{50}, $\#_{mergers}$,...
- **Environment**. $D_{x,y}$ (distance to the nearest halo B with mass over $y \times M_{vir}$ divided by r_{vir}^{B}). $N_{x,y}$ (# of neightbours with mass $> x \times M_{vir}$ in a radius y)
- **Lagrange volumes**. Selecting the particles: $1, 2, 3...8 \times r_{vir}$, r_{200}, Mainbranch, Tree approach. Defining the volume: cuboid, sphere, convex hull

Lagrange volumes

Same box. Different resolutions



F07: low res (128^3)

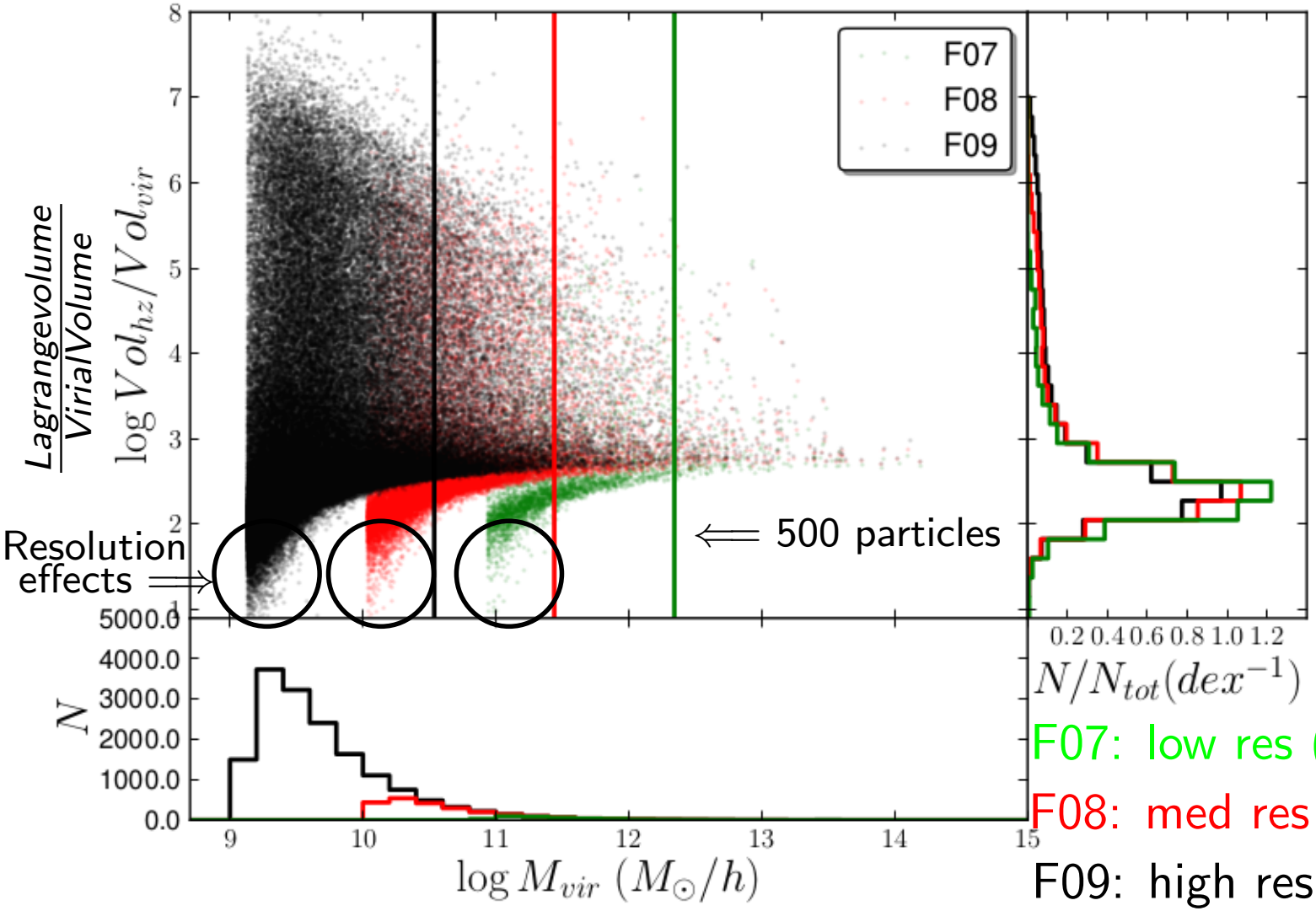
F08: med res (256^3)

F09: high res (512^3)

Lagrange volumes

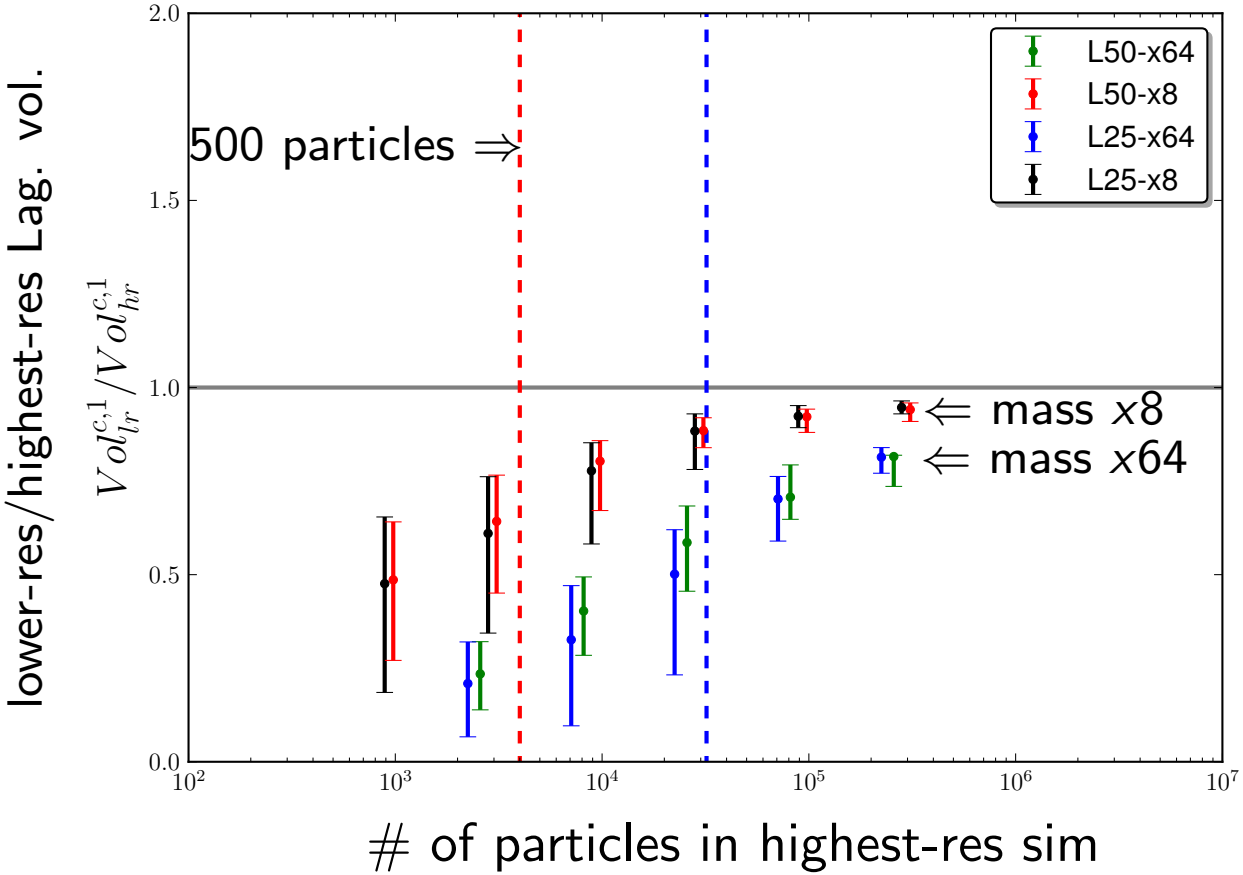
Same box. Different resolutions

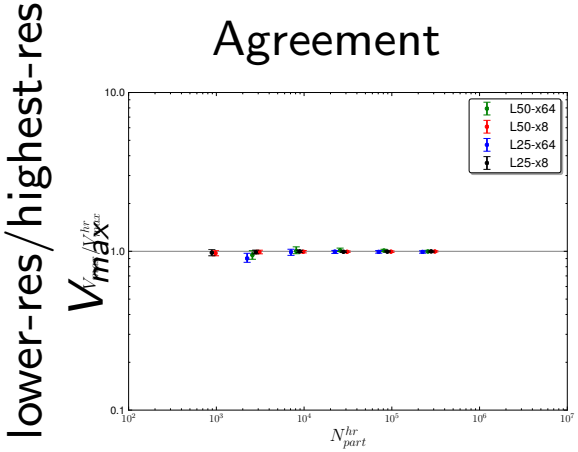
Normalize by $Vol_{vir} = \frac{4\pi}{3} r_{vir}^3$



Lagrange volumes: Resolution

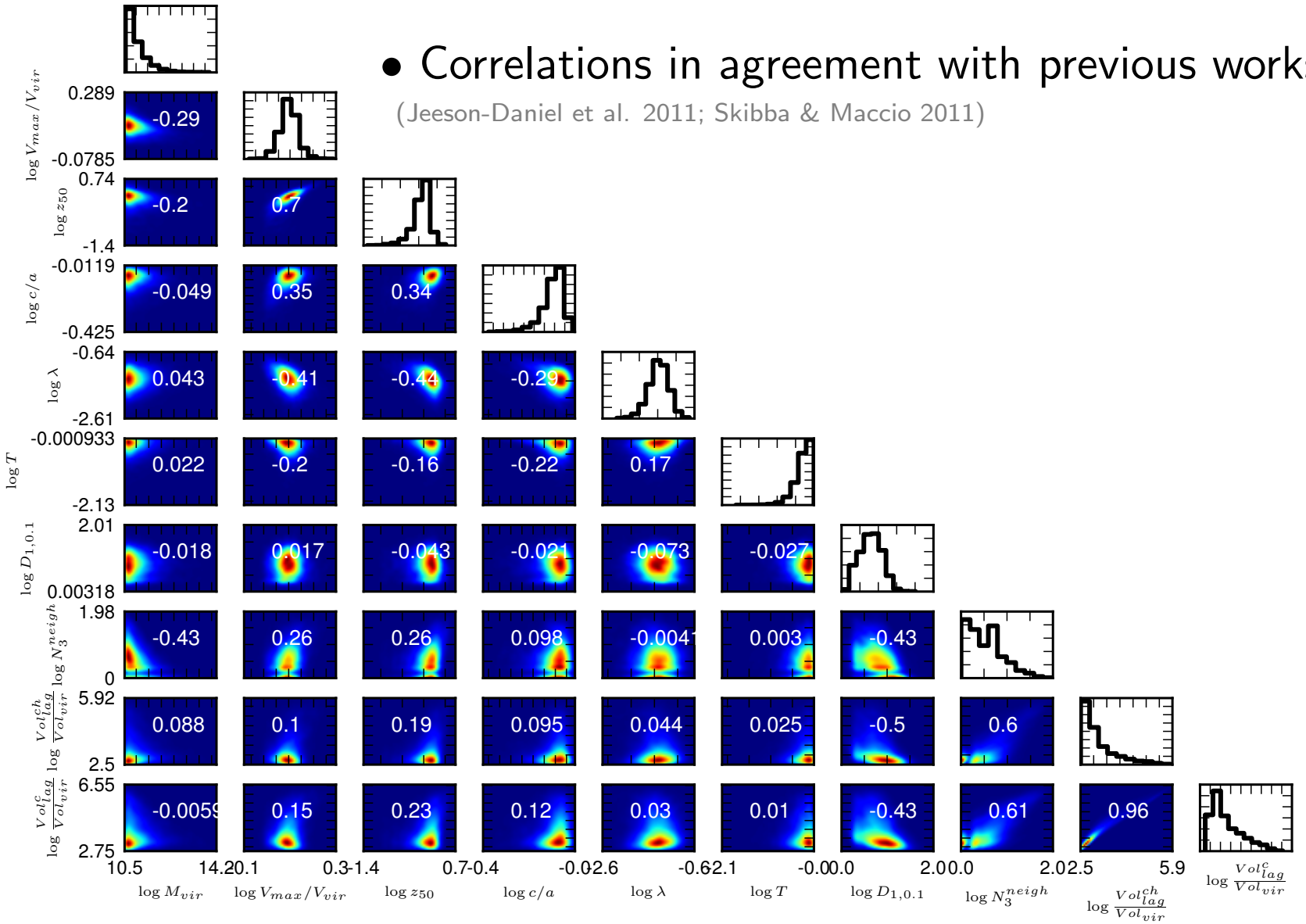
Same box. Different resolutions. No subhalos and $N_{part}^{hr} > 500$





- Single halo Lagrange volume increases with increasing resolution
- The smaller the level of zoom relative to initial box for Lagrange vol. calculation, the better for contamination

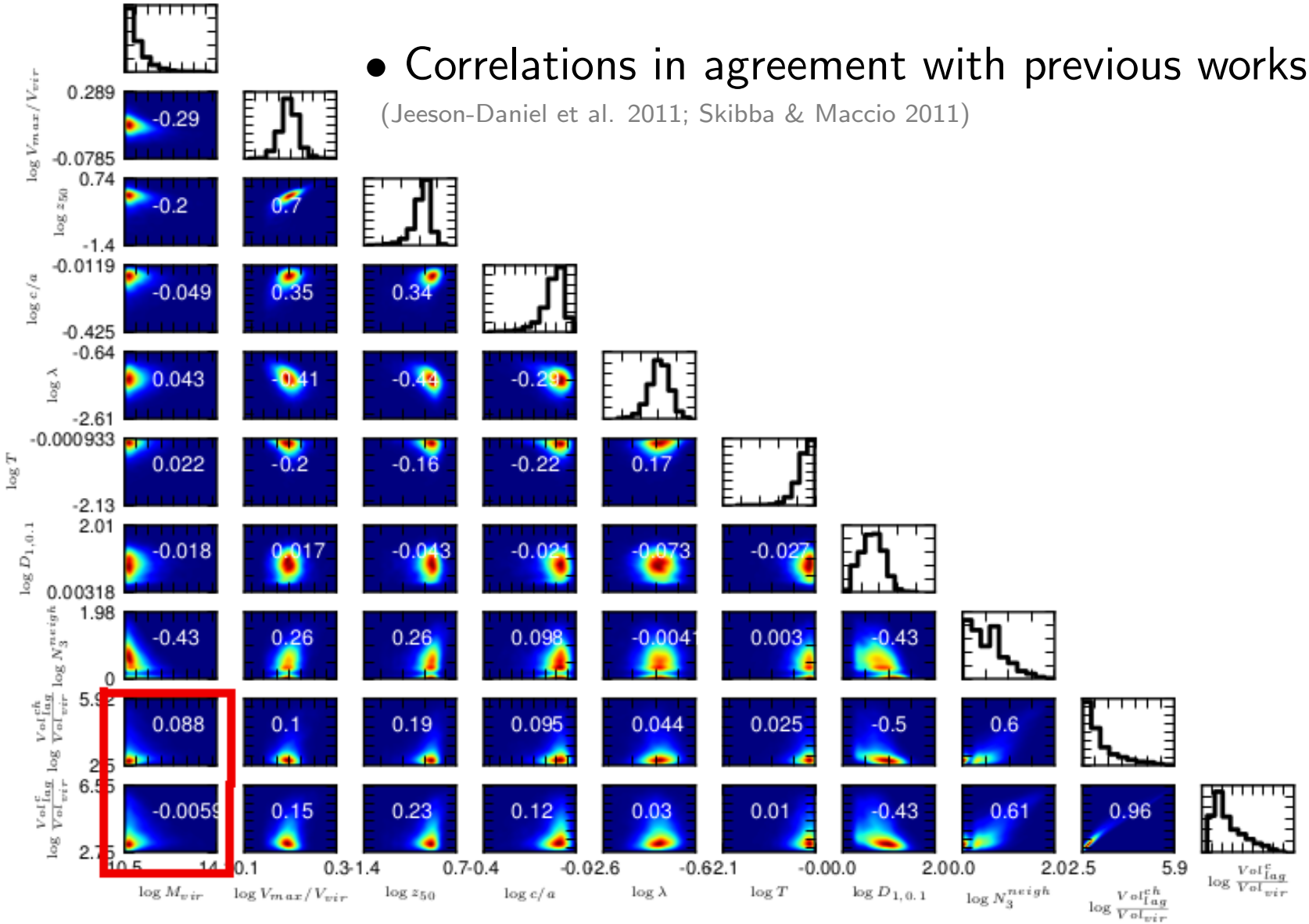
Correlations with other halo parameters



- Correlations in agreement with previous works

(Jeeson-Daniel et al. 2011; Skibba & Maccio 2011)

Correlations with other halo parameters



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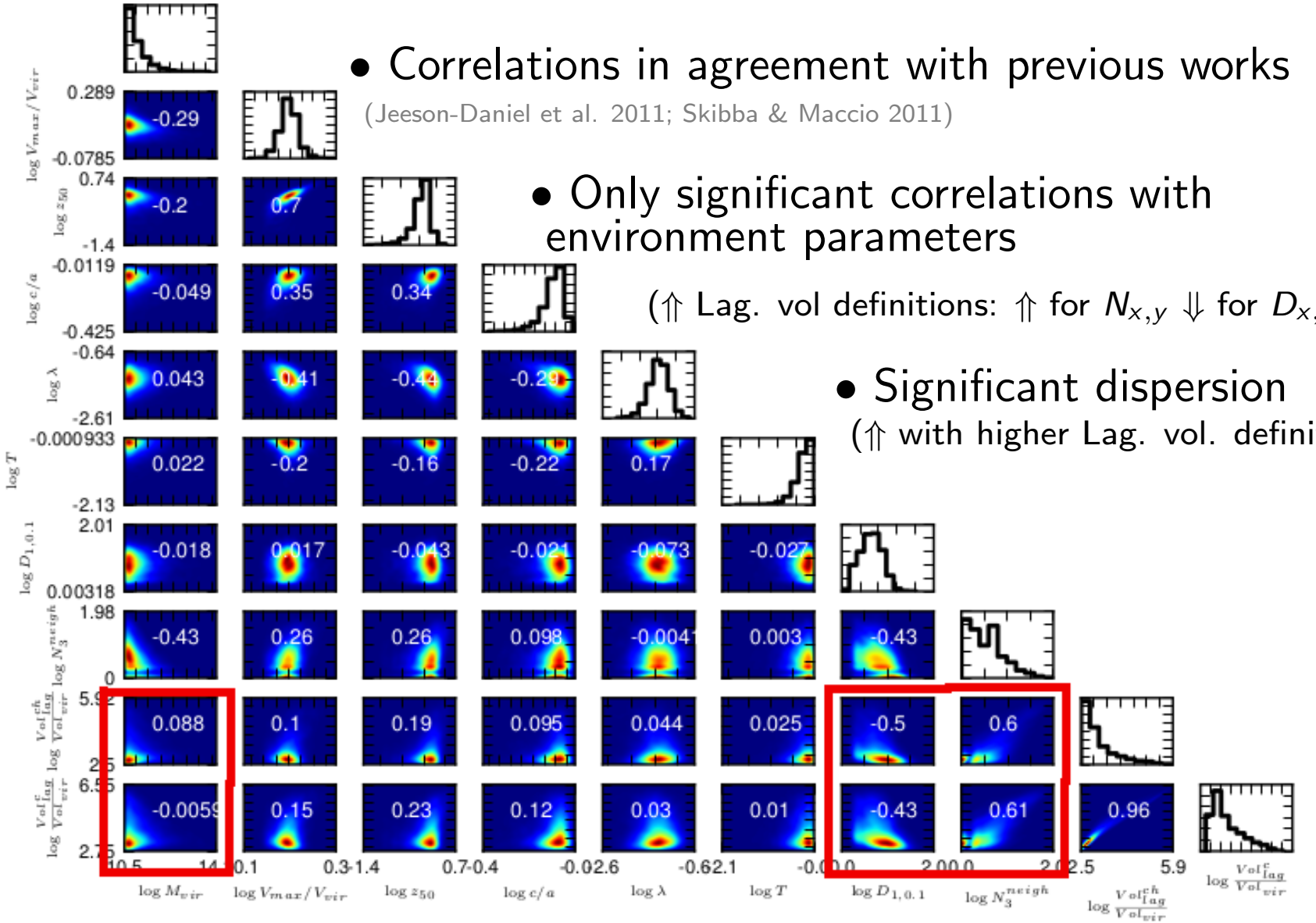
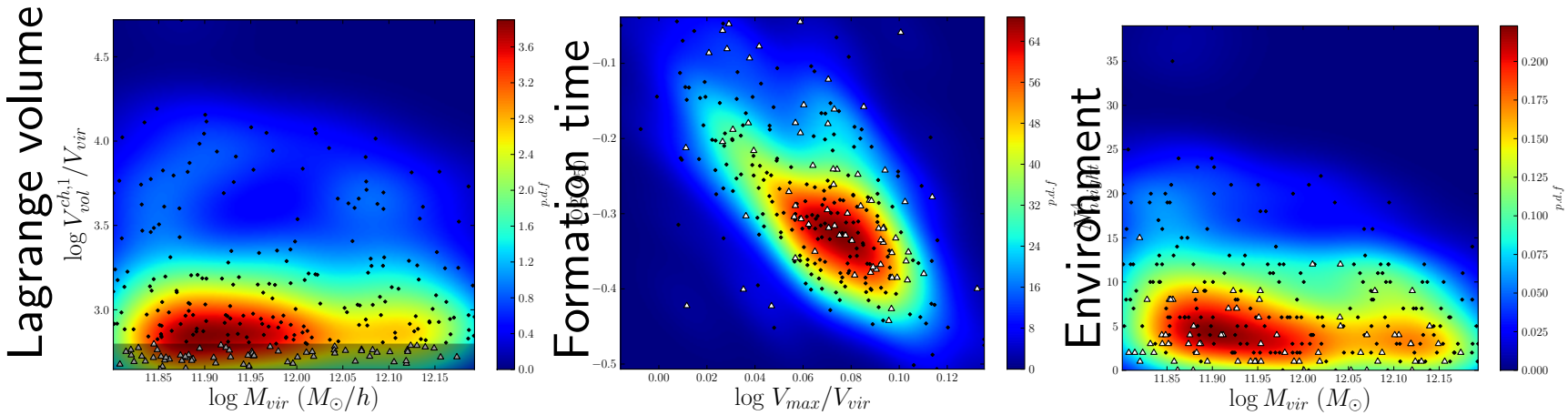


- Correlations in agreement with previous works
  (Jeeson-Daniel et al. 2011; Skibba & Maccio 2011)
- Only significant correlations with environment parameters
  (⇑ Lag. vol definitions: ⇑ for $N_{x,y}$ ⇓ for $D_{x,y}$)
- Significant dispersion
  (⇑ with higher Lag. vol. definitions)

Selecting your halo to zoom

How do these numbers translate when you want to zoom?



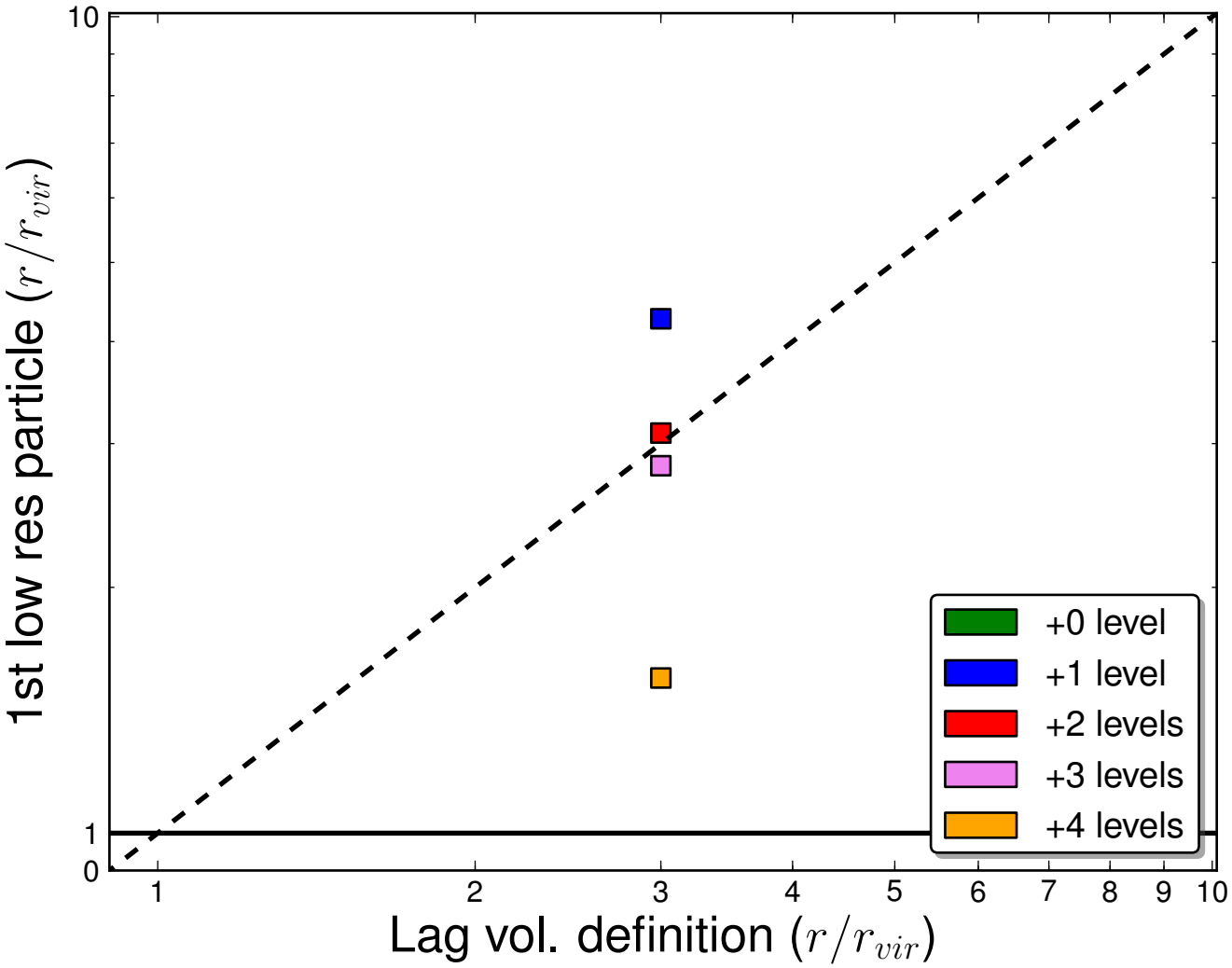
Pick smallest Lagrange volumes without biasing any internal halo properties or merger history

Part II: Let's zoom!

Zoom-in simulations

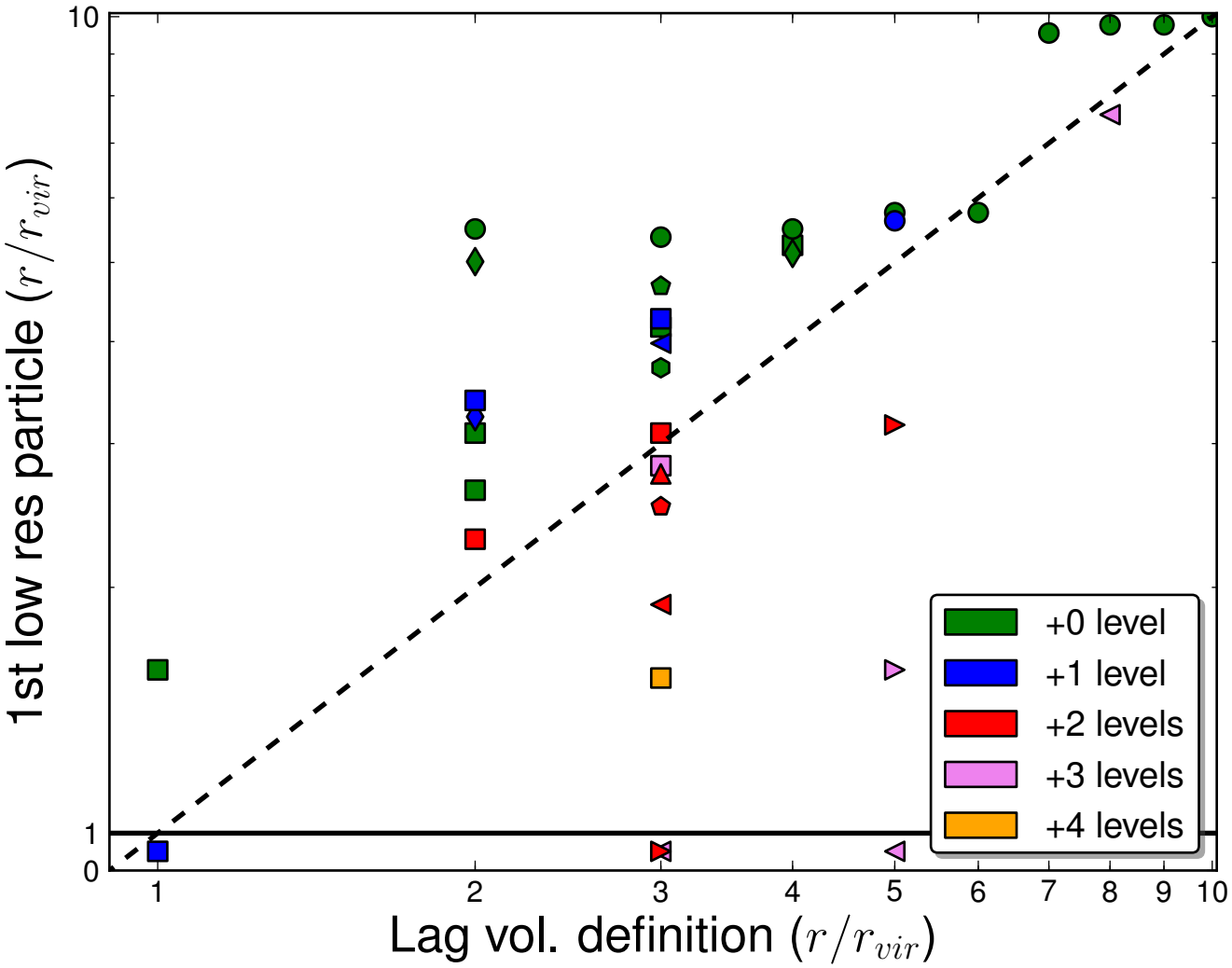
- resolution: 512^3, 1024^3, 2048^3, 4096^3, 8192^3.
- L_{box} : $5, 50, 650$ Mpc/h
- codes: `GADGET` and `ENZO`
- hydro: adiabatic test runs

Contamination



For the same halo and fixed Lagrange volume, risk of contamination increases with resolution

Contamination

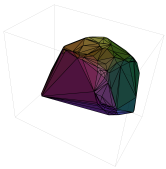


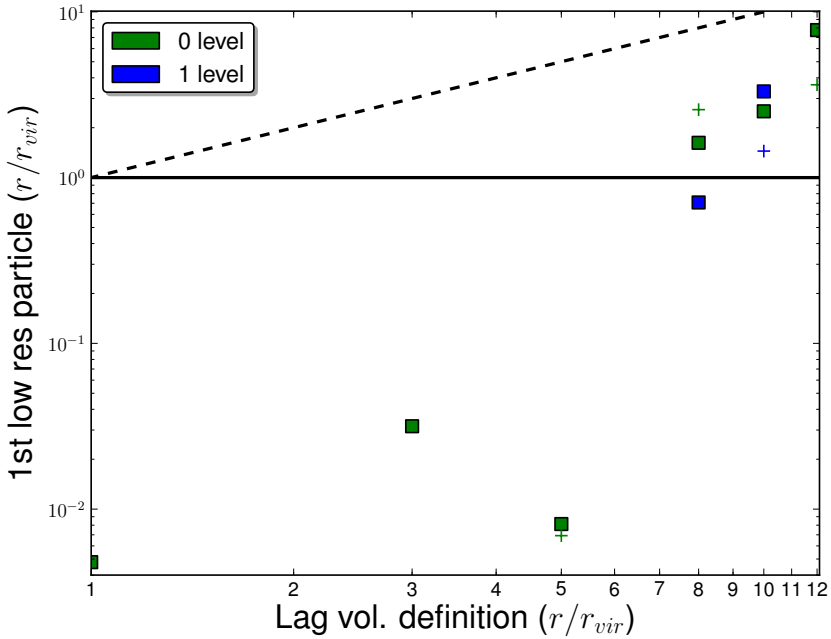
For the same halo and fixed Lagrange volume, risk of contamination increases with resolution

Recipe to minimize Lagrange volume and guarantee no contamination

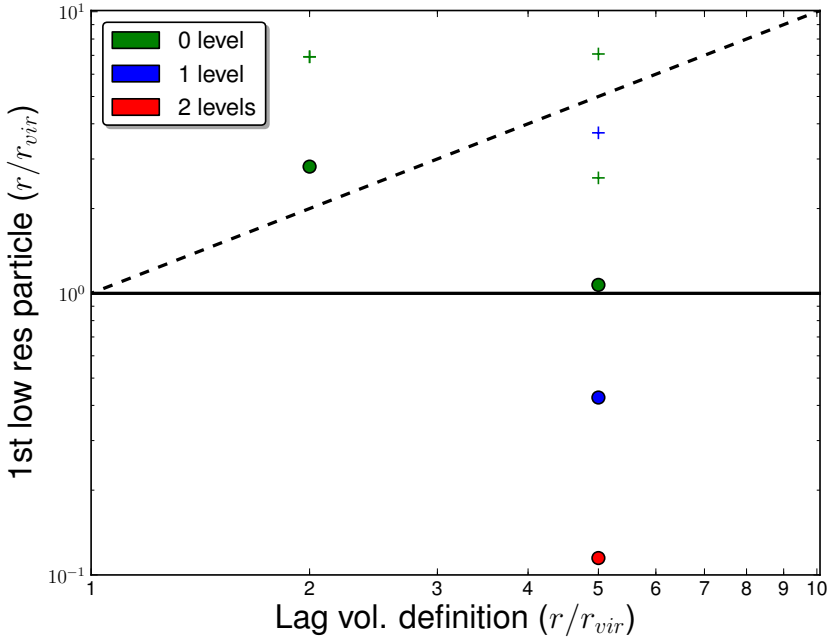
Other Definitions/Codes

Convex hull definition





Also for ENZO

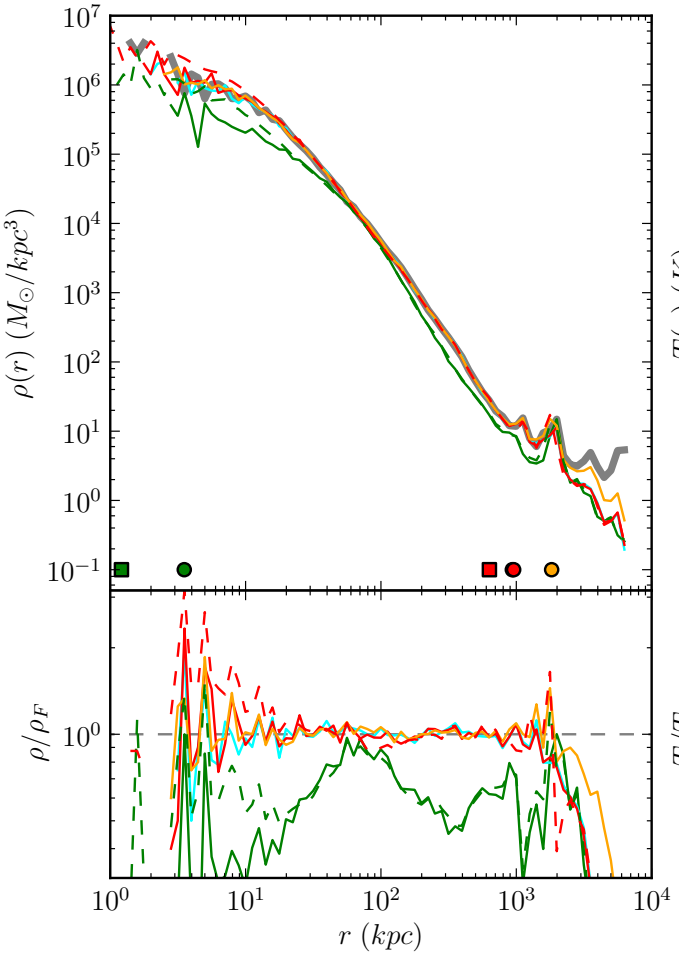


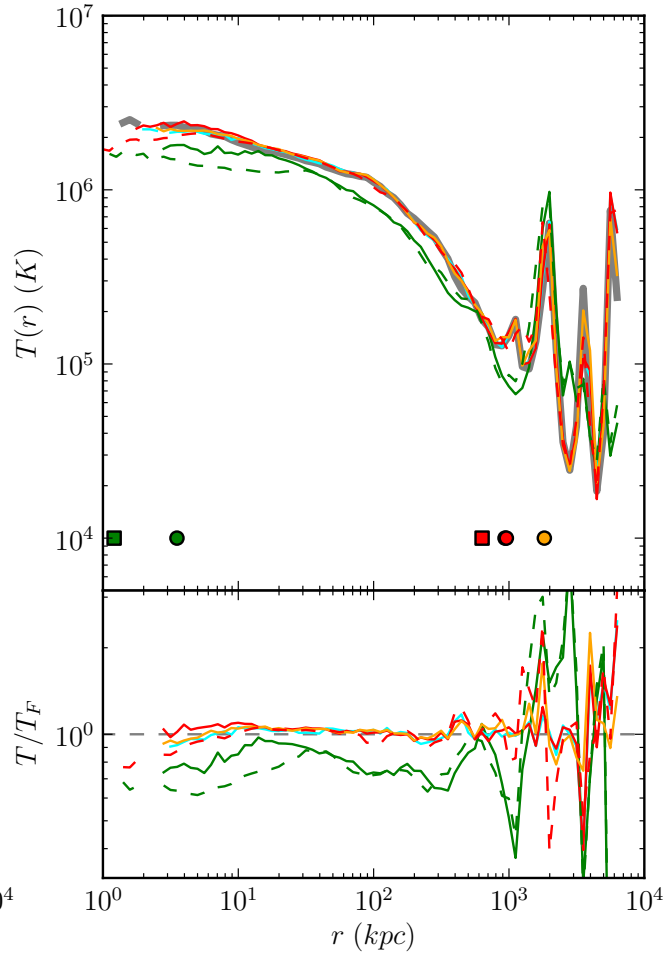
For the same halo and fixed Lagrange volume, risk of contamination increases with resolution

Why bother?

Adiabatic test simulations

Gas Density





Temperature

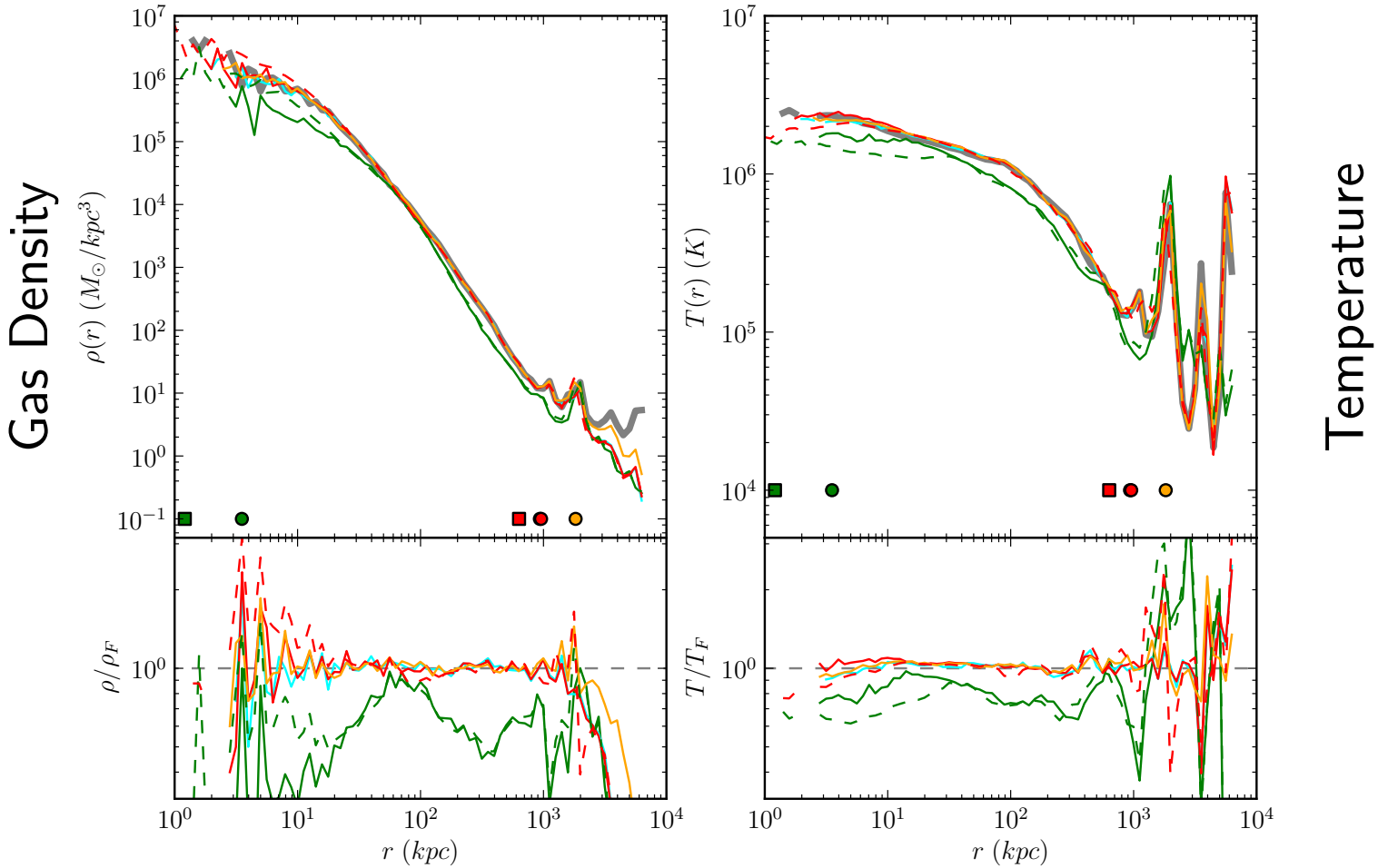
Grey lines: $L_{box} = 50 Mpc/h$ full box results: 512^3

Red and orange lines: non-contaminated runs: 512^3 and 1024^3

Green lines: contaminated runs: 512^3 and 1024^3

Why bother?

Adiabatic test simulations



Contaminated density and temperature too low by factors of 1.5-2

Conclusions

- There is room to improve the zoom-in technique pipeline, primarily via choosing the Lagrange volume appropriately
- Halos may be selected with small Lagrange volume without biasing (spin, concentration, formation time, etc) $\rightarrow$ Important to select halos to zoom and save cpu time!
- Lagrange volume increases with resolution. If you measure Lagrange volume using low-resolution simulations you risk severe contamination in the zoom
- We have developed recipes to minimize the Lagrange volume (cost) and guarantee no contamination for specific Lagrange volume definitions and codes