The Boosted Potential

Jens Stücker

In Collaboration with:

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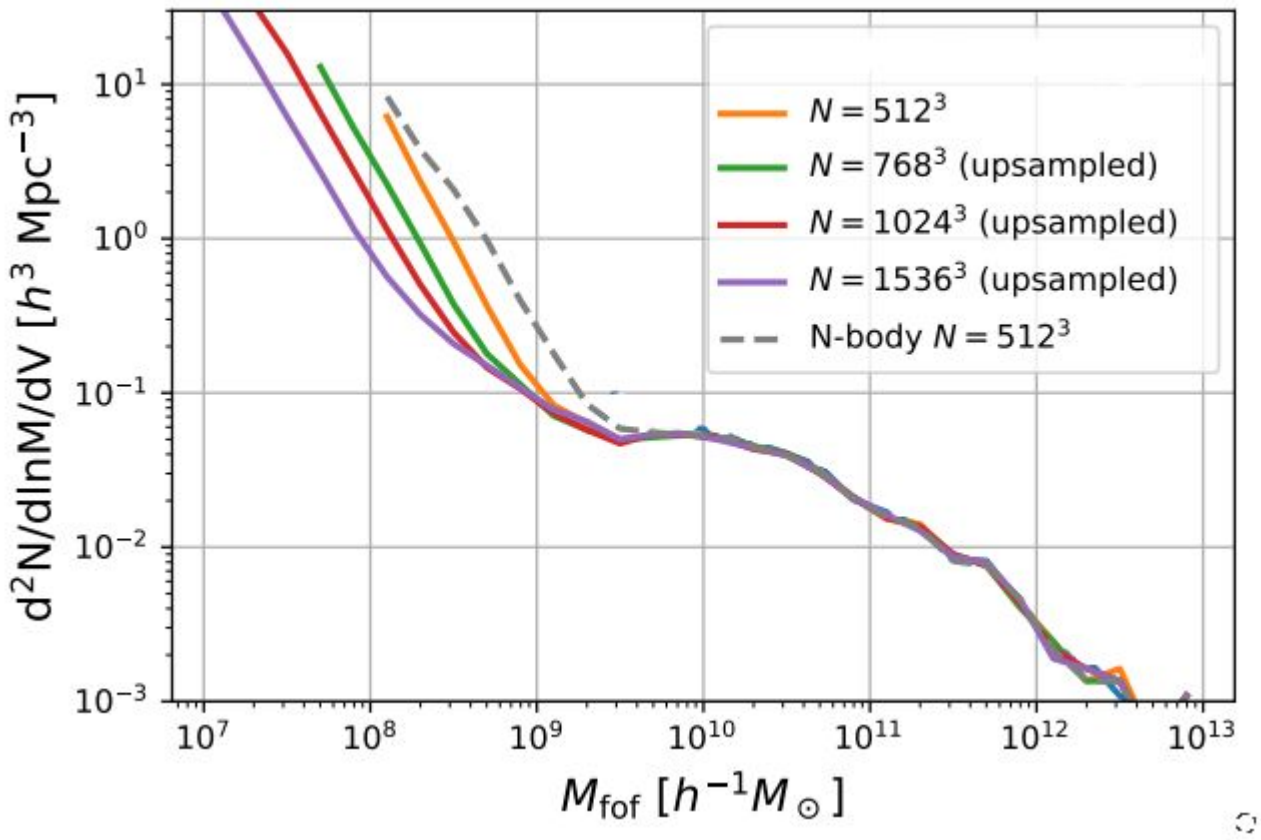
Cosmology from Home

Stücker et al (2020, 2021)

The Friends of Friends-mass Function in WDM Simulations without artificial fragments



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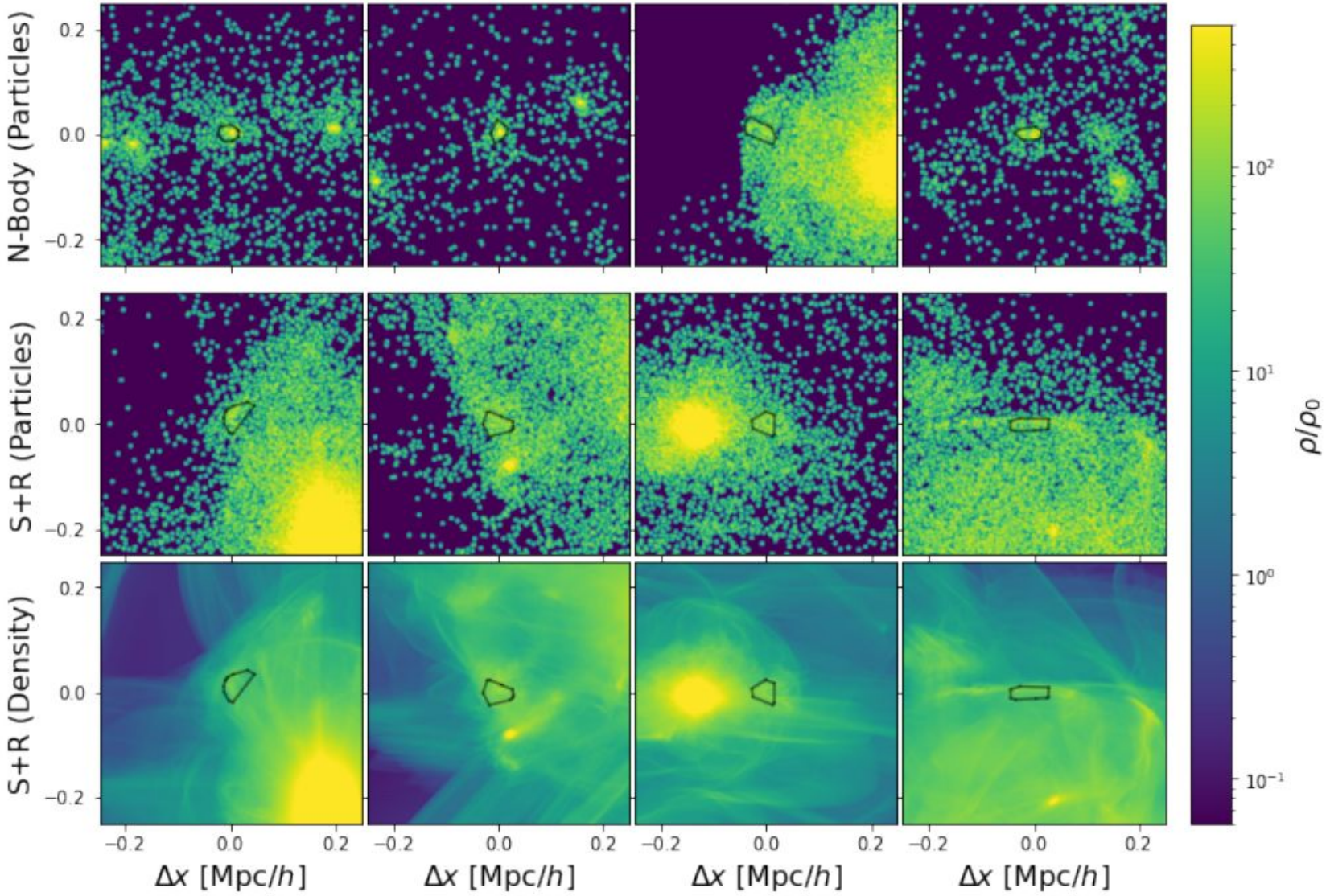
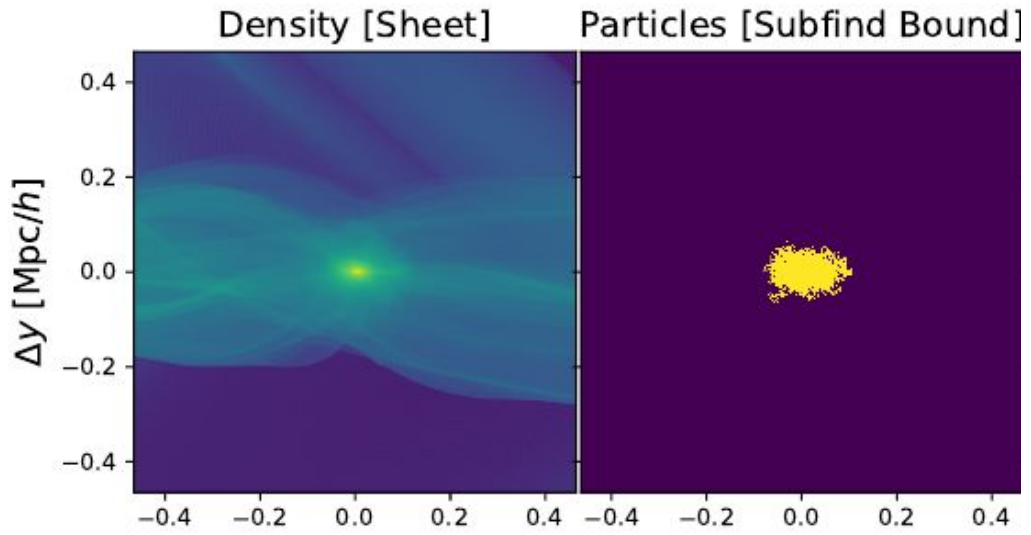
Typical objects with M = 5e8 Msol

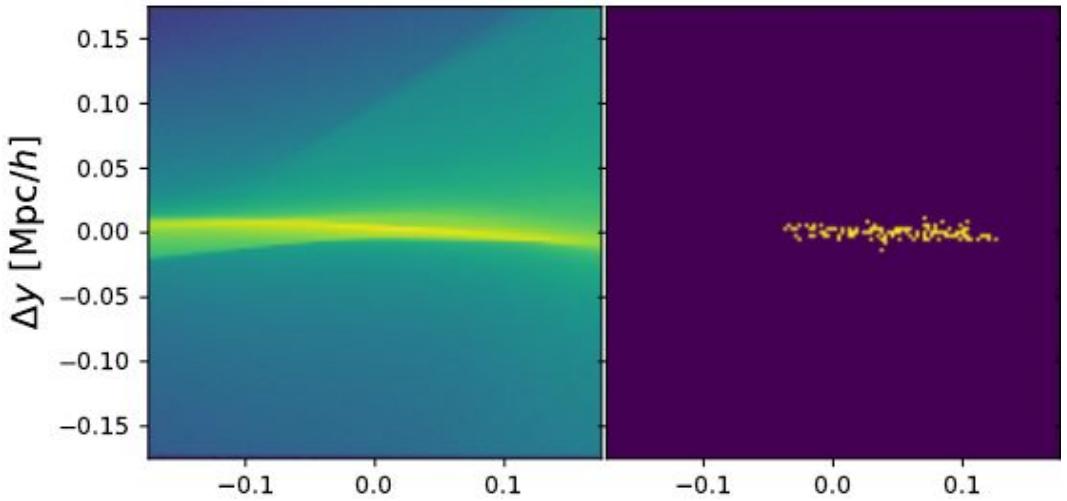


A problem with halo finders (in Warm DM simulations)

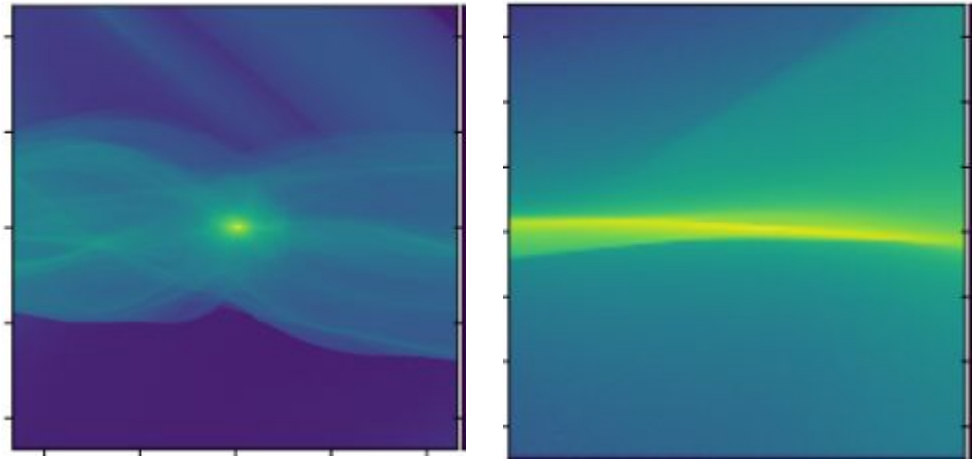
- **Normal Halo:**



- **Misidentified Halo:**



What is a Halo?



- An Overdensity $\langle \rho/\rho_0 \rangle > 200$ ✓ ✓
- Something collapsed in 3D ✓ ✗
- A bound object ✓ ??

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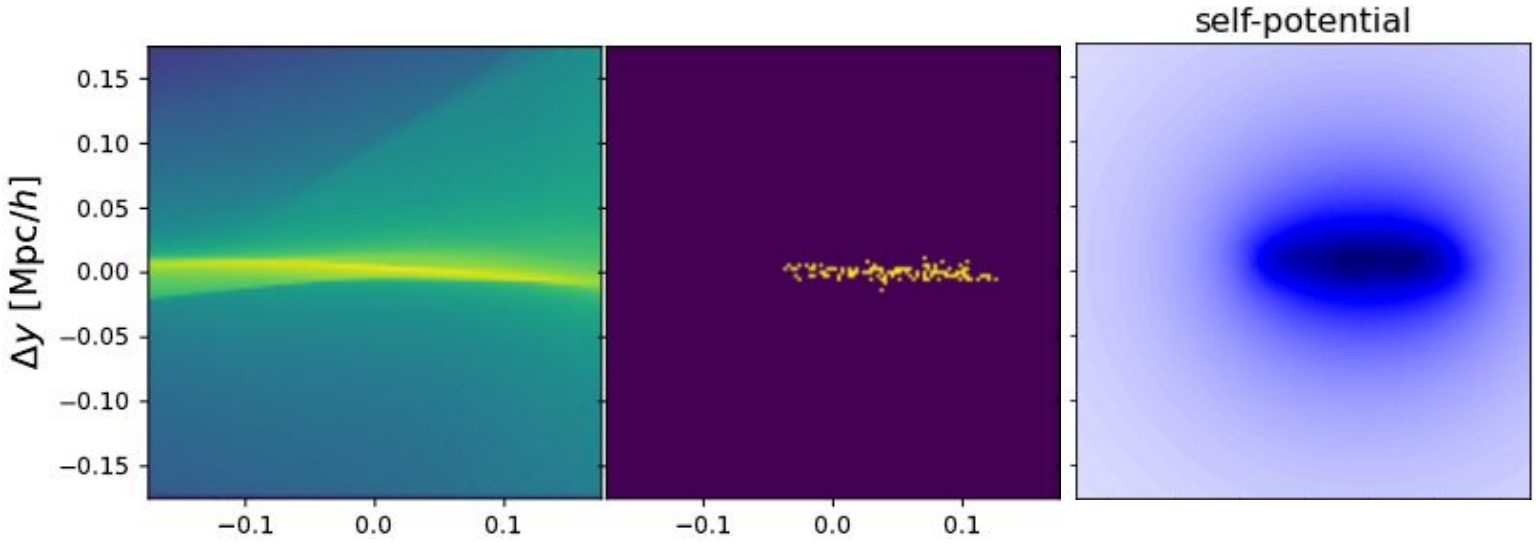
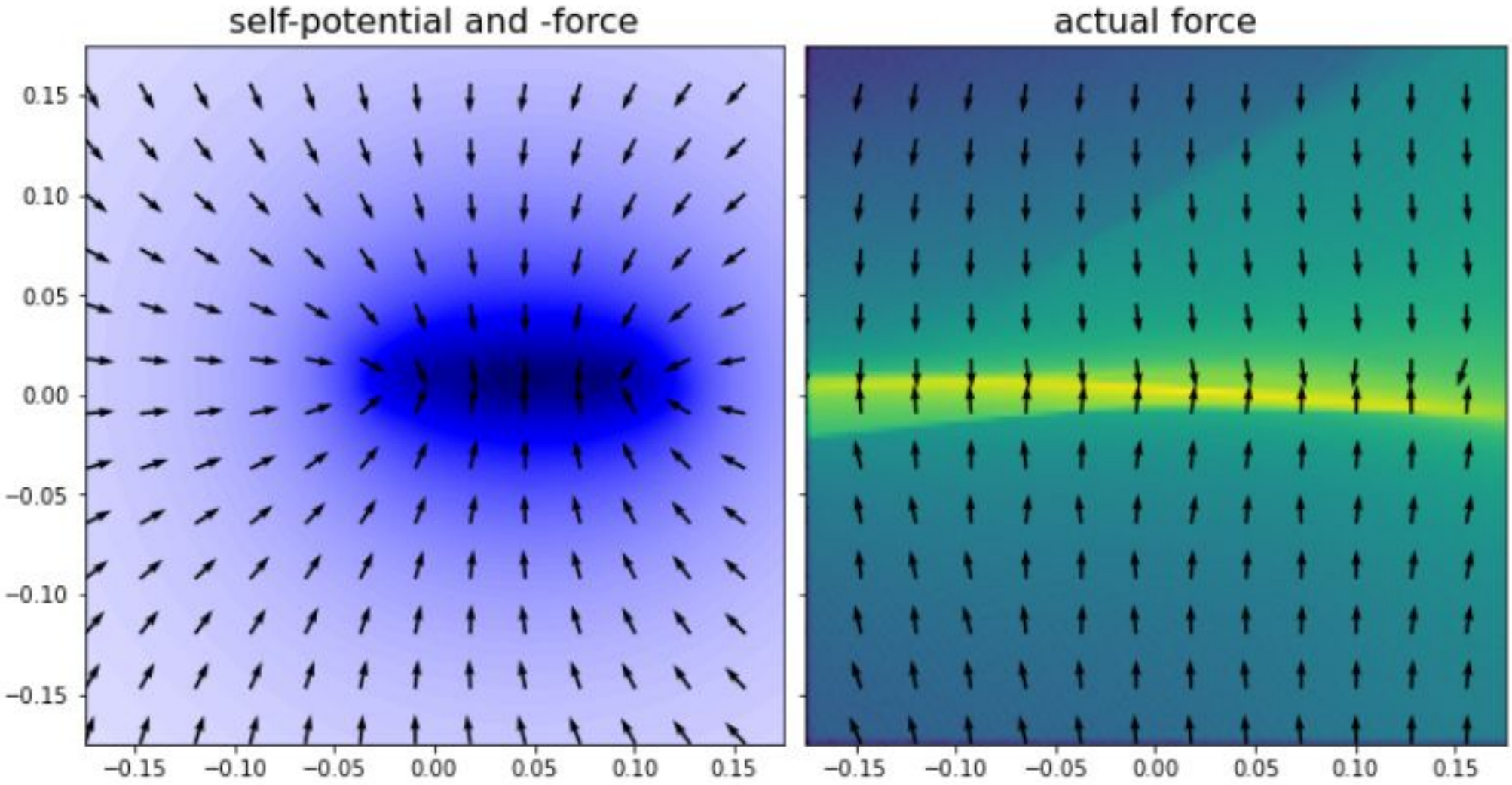
The self-potential Binding Check



- **Subfind Binding Check**

The self-potential Binding Check



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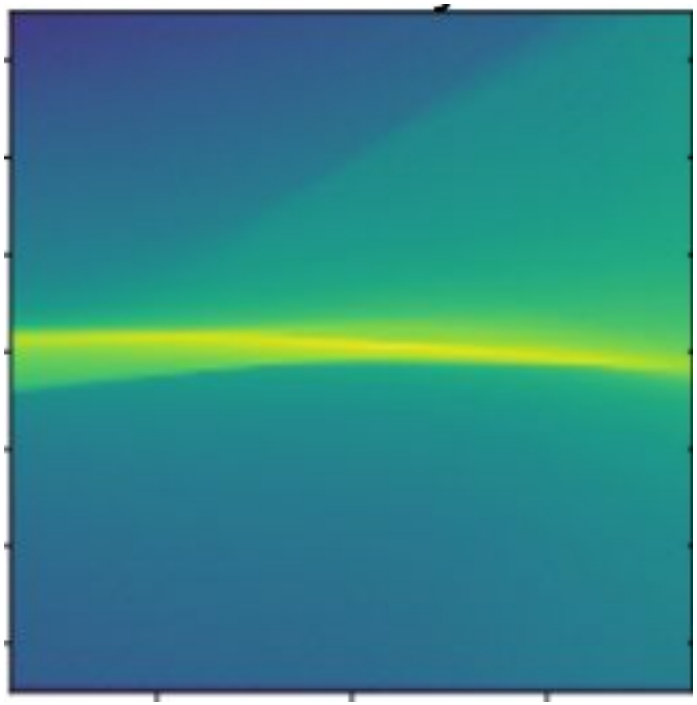
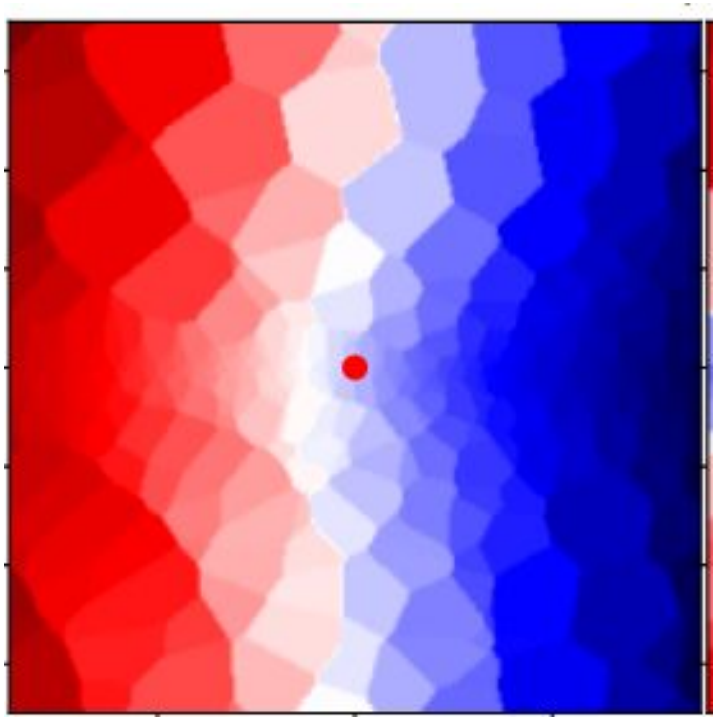
The self-potential Binding Check

- The self-potential is a constructed quantity
- Depends heavily on FoF pre-selection
- Neglects external Tidal fields

=> Use the global potential field ?

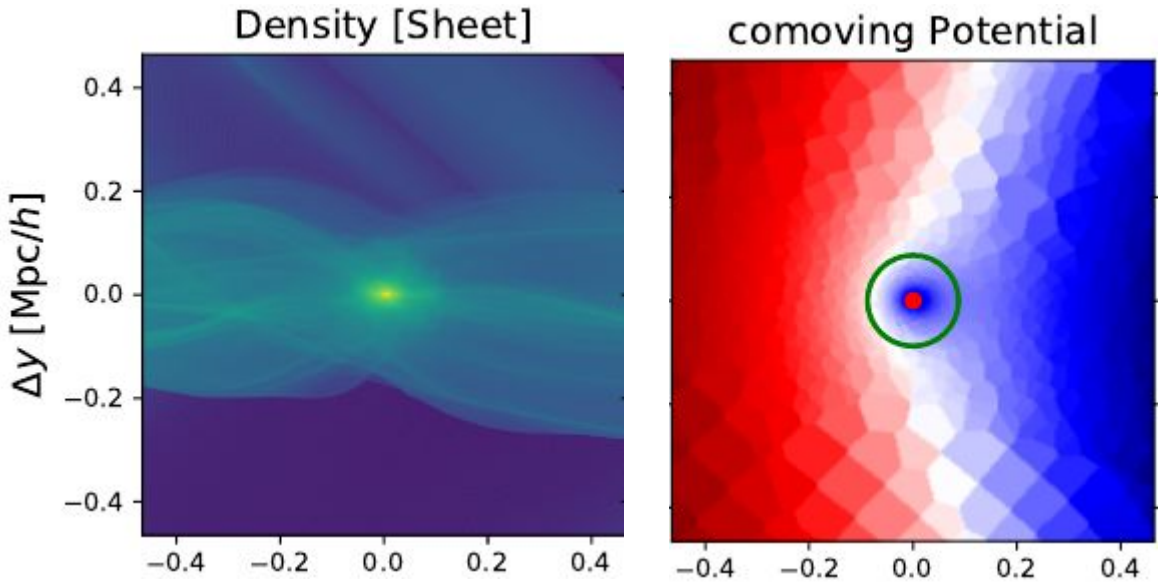
The global potential





The potential (?!)

The global Potential



- Includes the effect of all particles
- Dominated by large scale gradients

An accelerated frame of reference

- **Switch to an accelerated frame:**

$$\boldsymbol{x} \rightarrow \boldsymbol{x} - \boldsymbol{v}_0 t - \frac{1}{2}\boldsymbol{a}_0 t^2$$

- **Introduces an apparent force**

  = global gradient in the potential

$$\phi_{\text{boost}}(\boldsymbol{x}) = \phi(\boldsymbol{x}) + \boldsymbol{a}_0 \cdot \boldsymbol{x}$$

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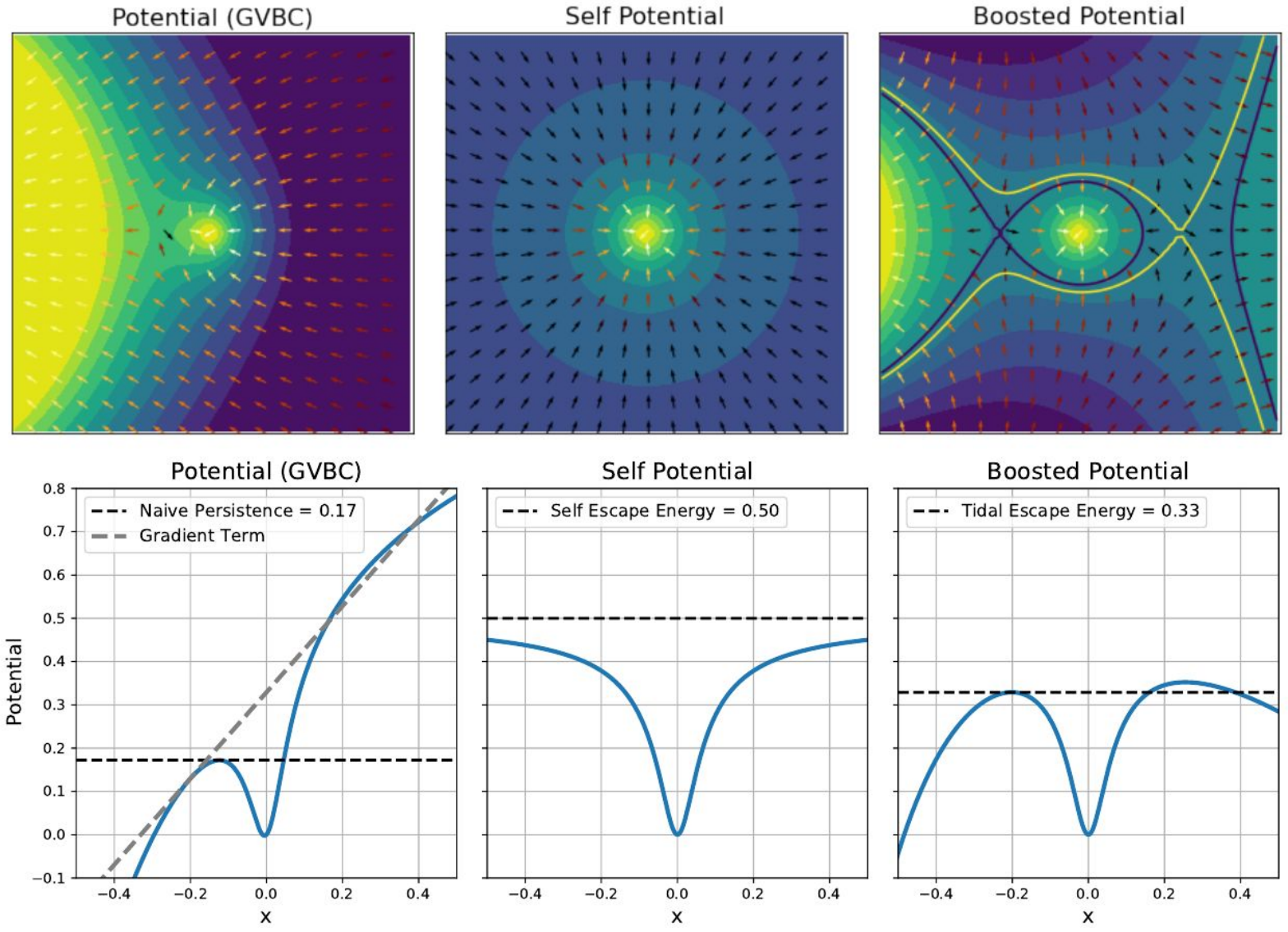
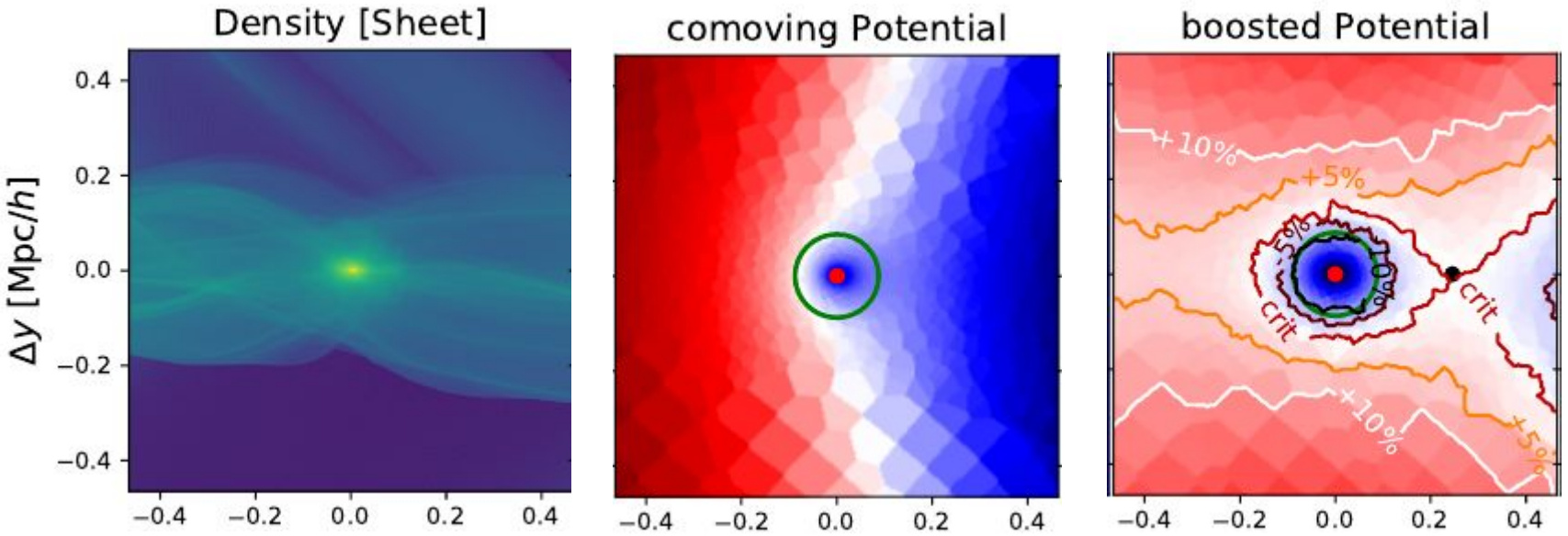
The boosted Potential



The boosted Potential



- **Switching to the accelerated frame removes the global gradient**

$$\phi_{\mathrm{boost}}(\boldsymbol{x}) = \phi(\boldsymbol{x}) + \boldsymbol{a}_0 \cdot \boldsymbol{x}.$$

- **Natural frame for a freely falling halo**

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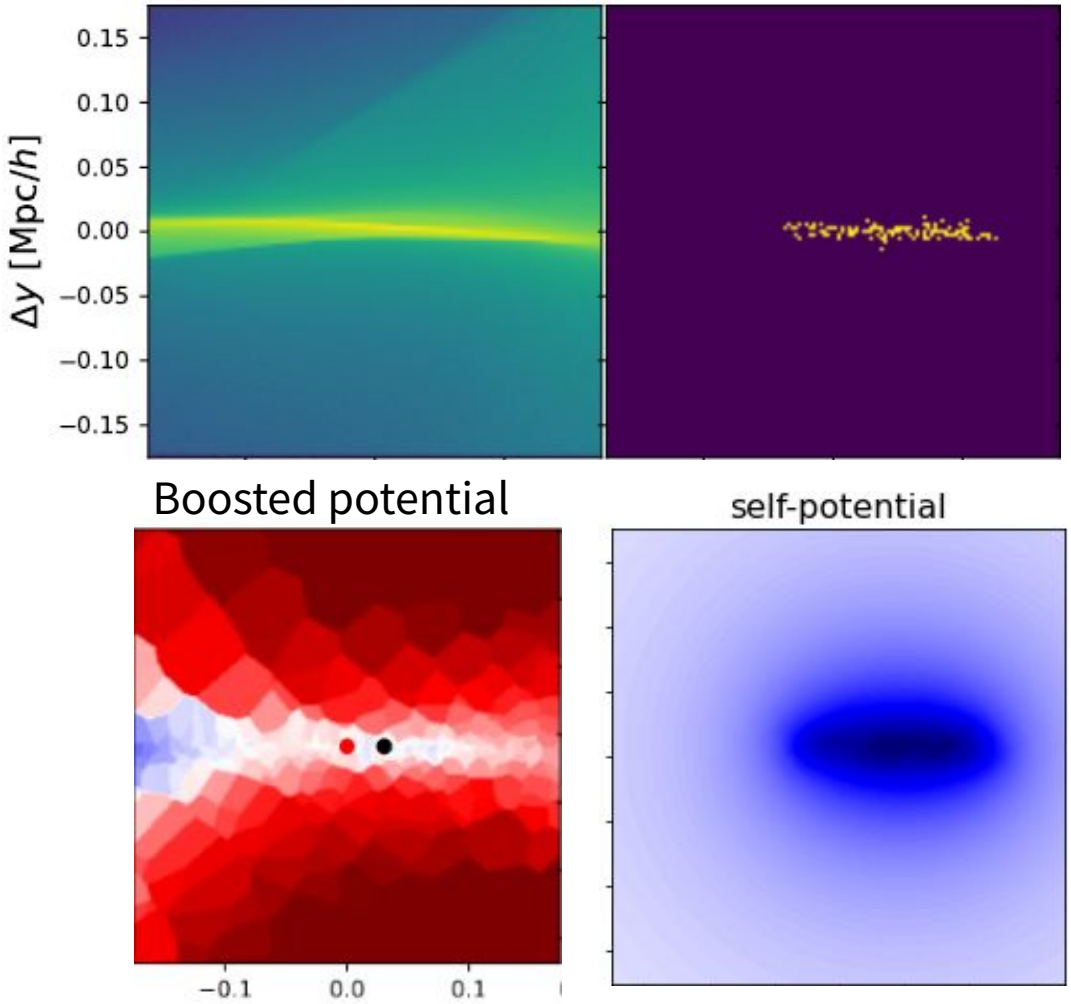
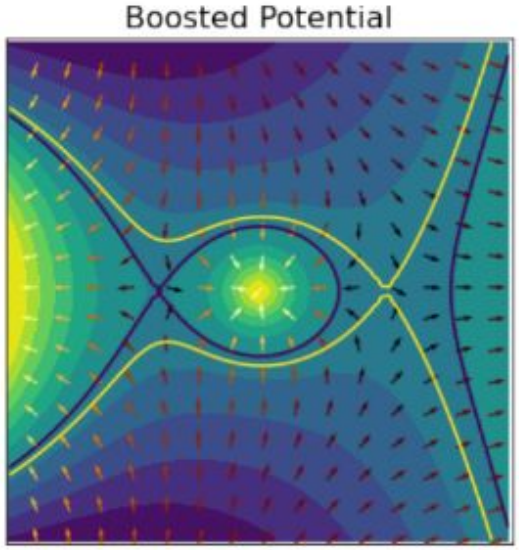
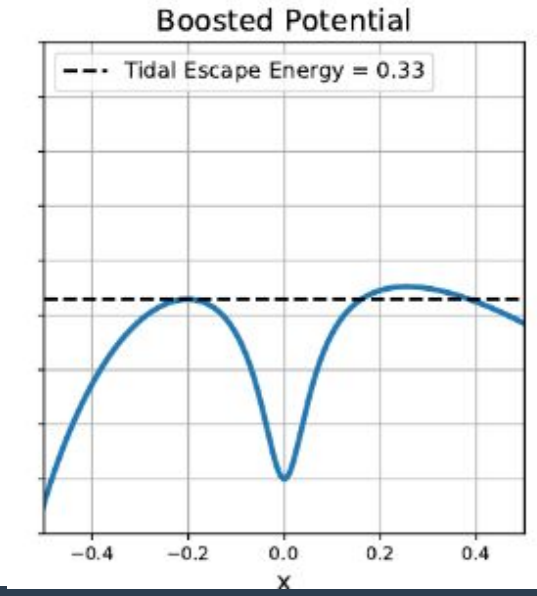
The boosted potential binding check



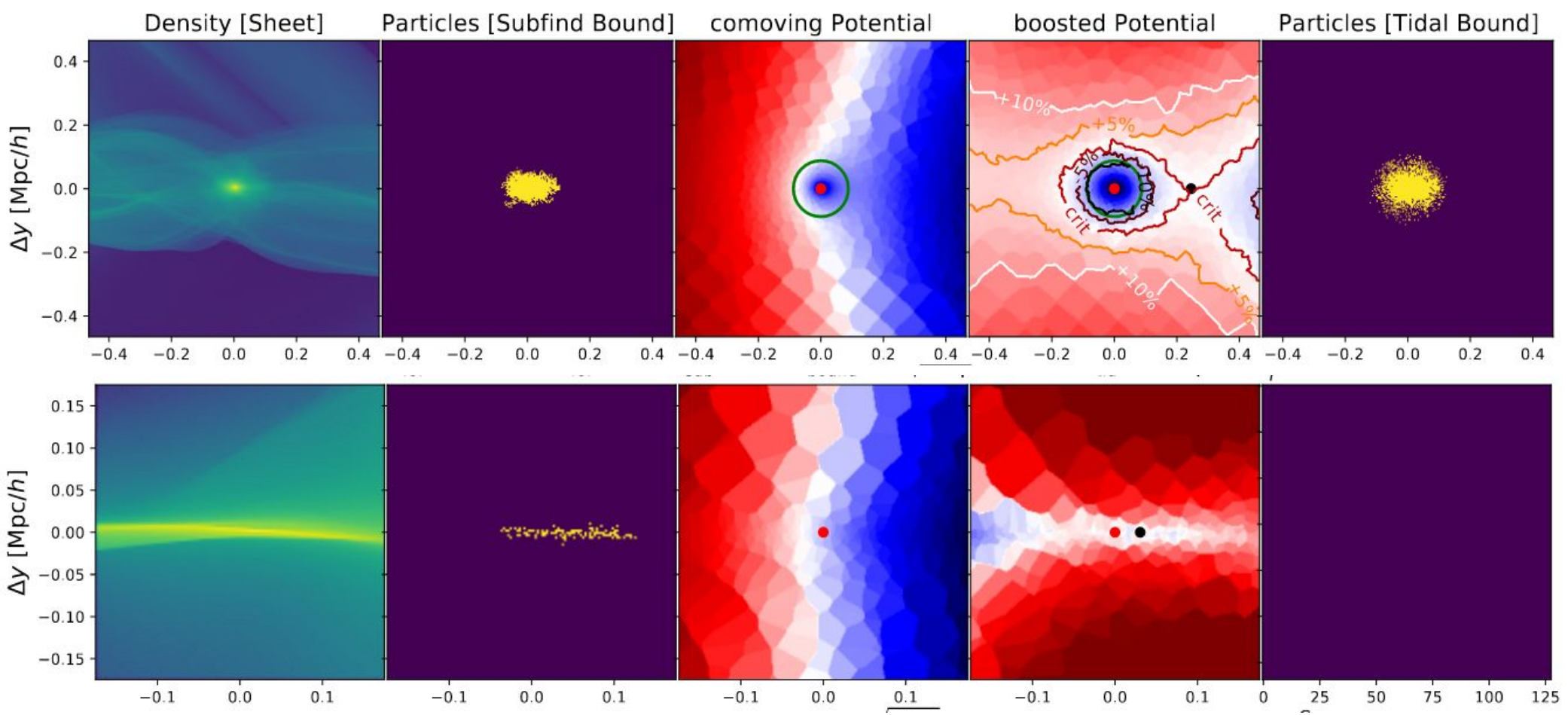
The boosted potential binding check



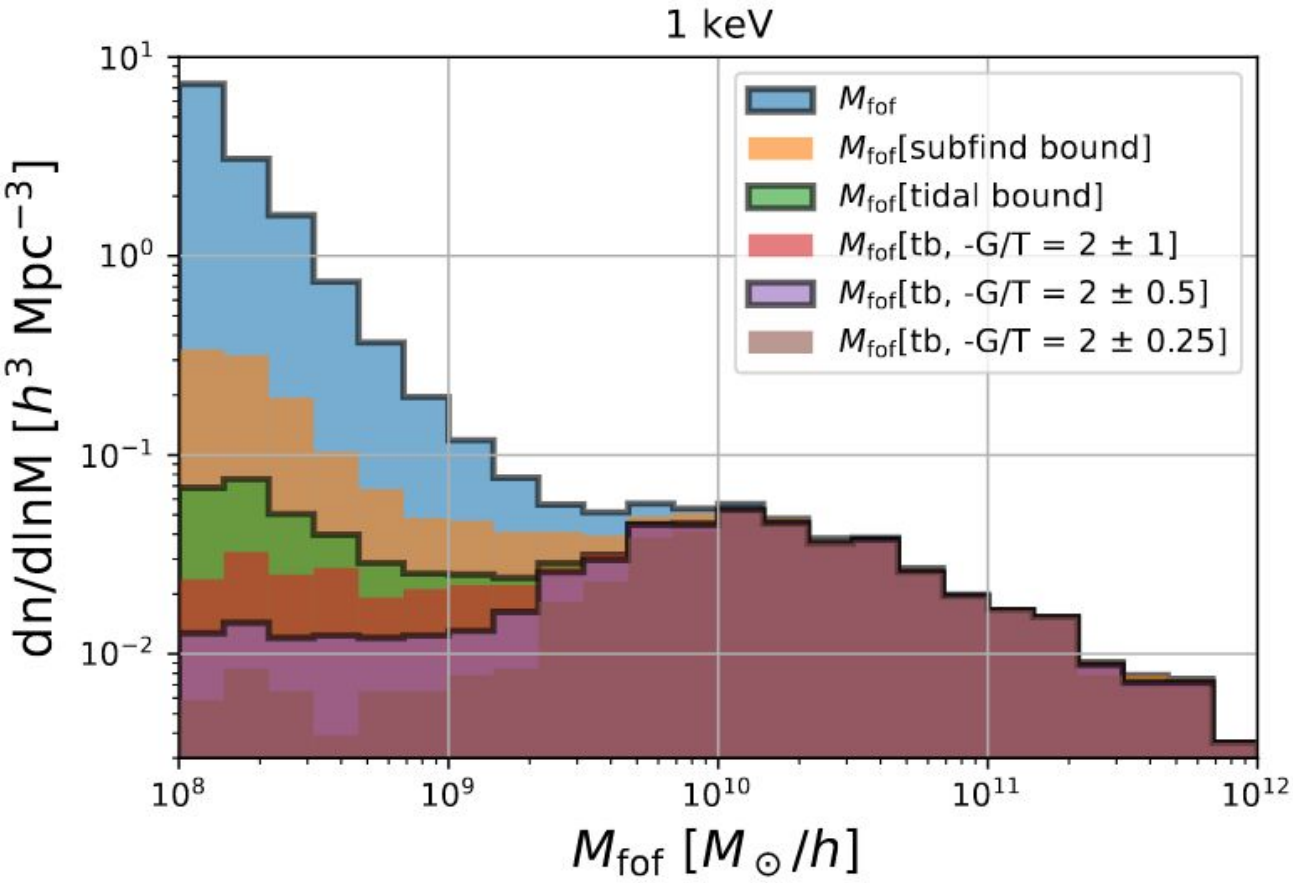


- Critical energy level Φ_{saddle}
- The critical contour defines the **tidal boundary**
- Particles with $E > \Phi_{saddle}$ can **escape** the object
- Particles with $E < \Phi_{saddle}$ are **bound**

The boosted potential binding check

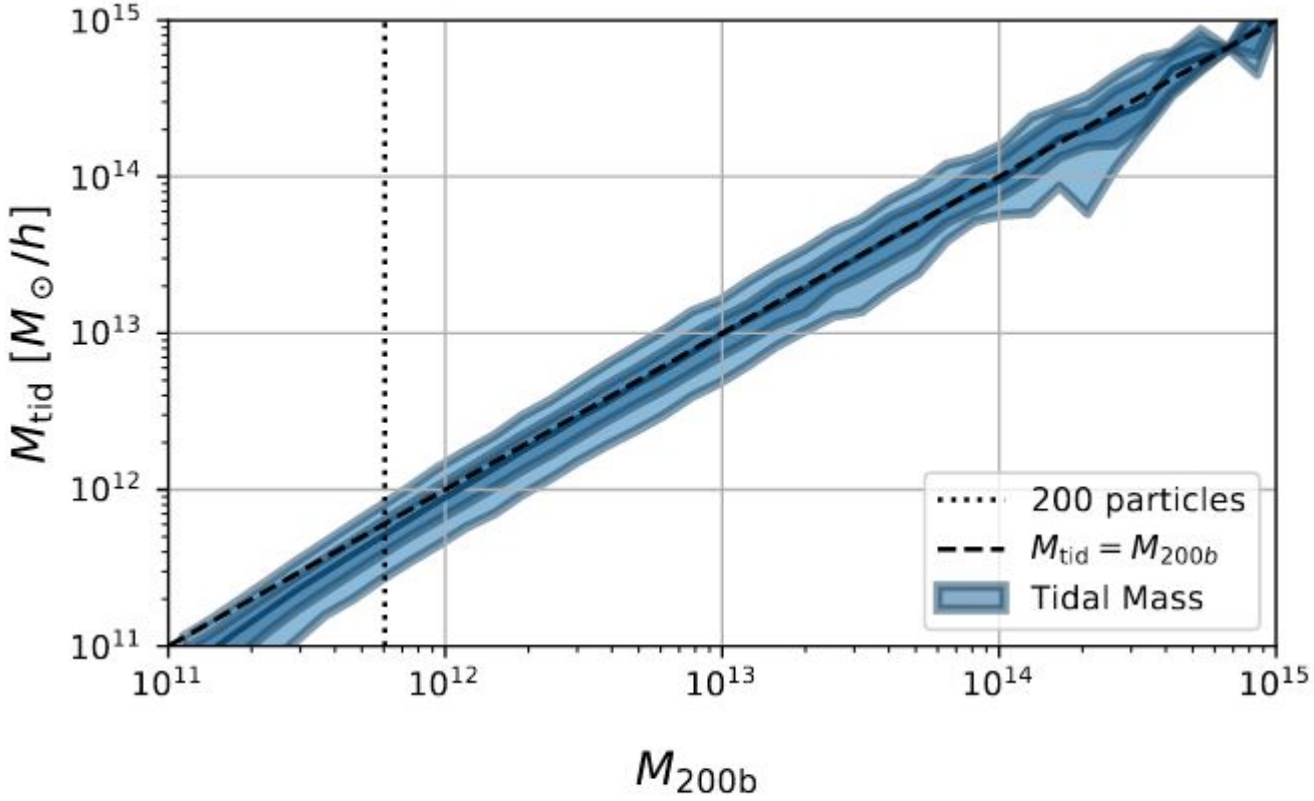


WDM Haloes at small masses



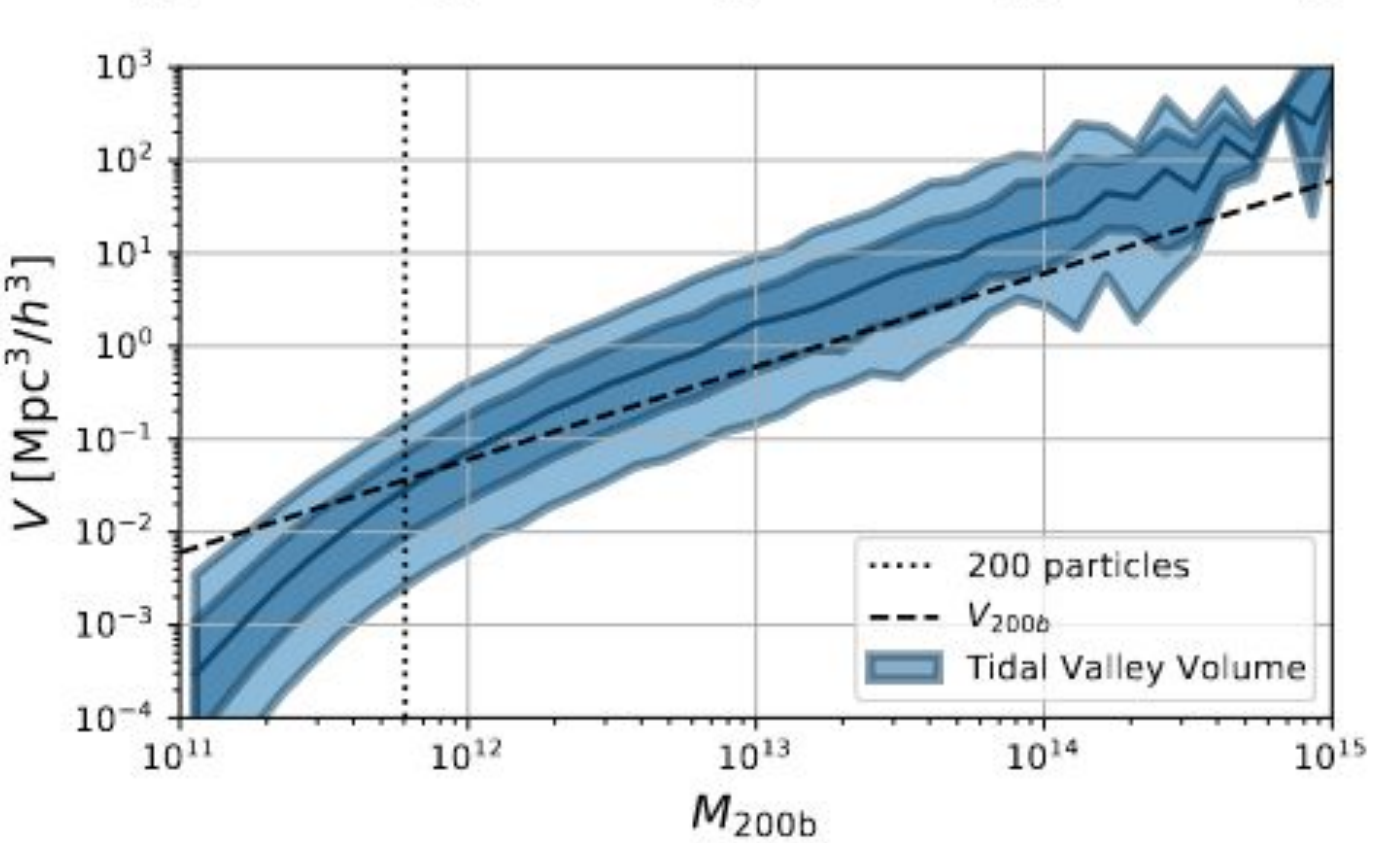
Stücker et al. (2021)

The “Tidal Mass”

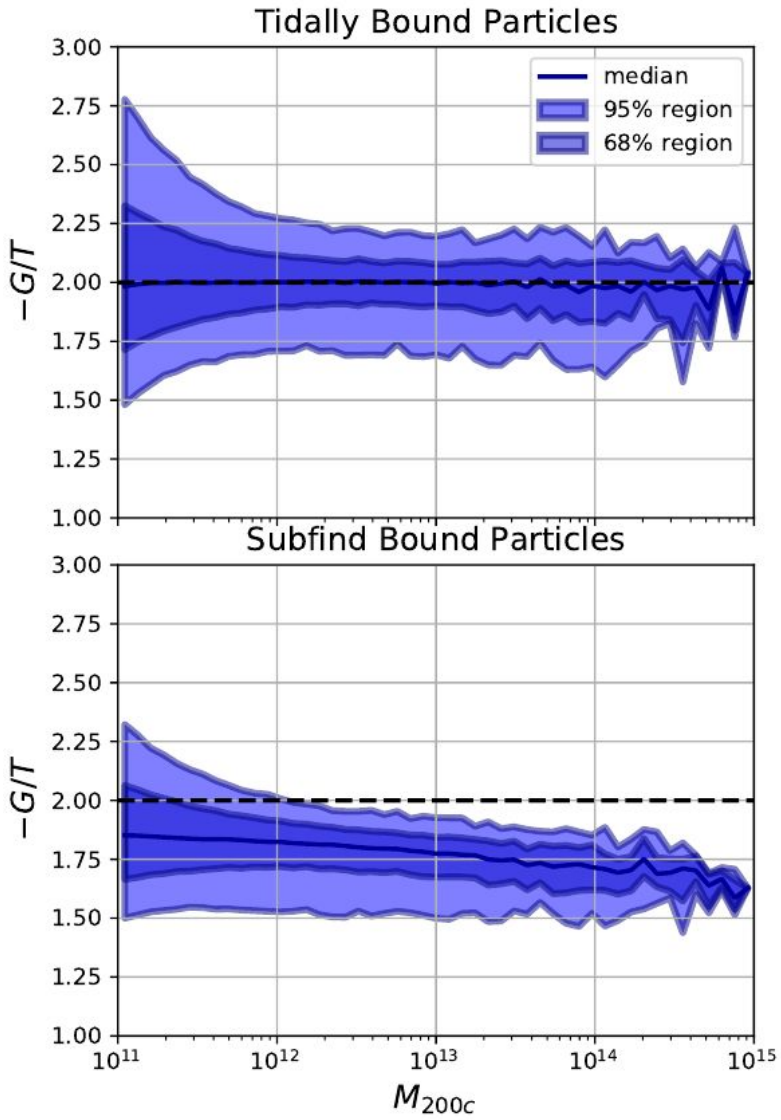


(CDM simulations)

The “Tidal Boundary”



The Virial Theorem and the Binding Check



$$G := \langle \boldsymbol{a} \cdot (\boldsymbol{x} - \langle \boldsymbol{x} \rangle) \rangle$$

$$T := \frac{1}{2} \left\langle (\boldsymbol{v} - \langle \boldsymbol{v} \rangle)^2 \right\rangle$$

$$-G \,/\, T = 2$$

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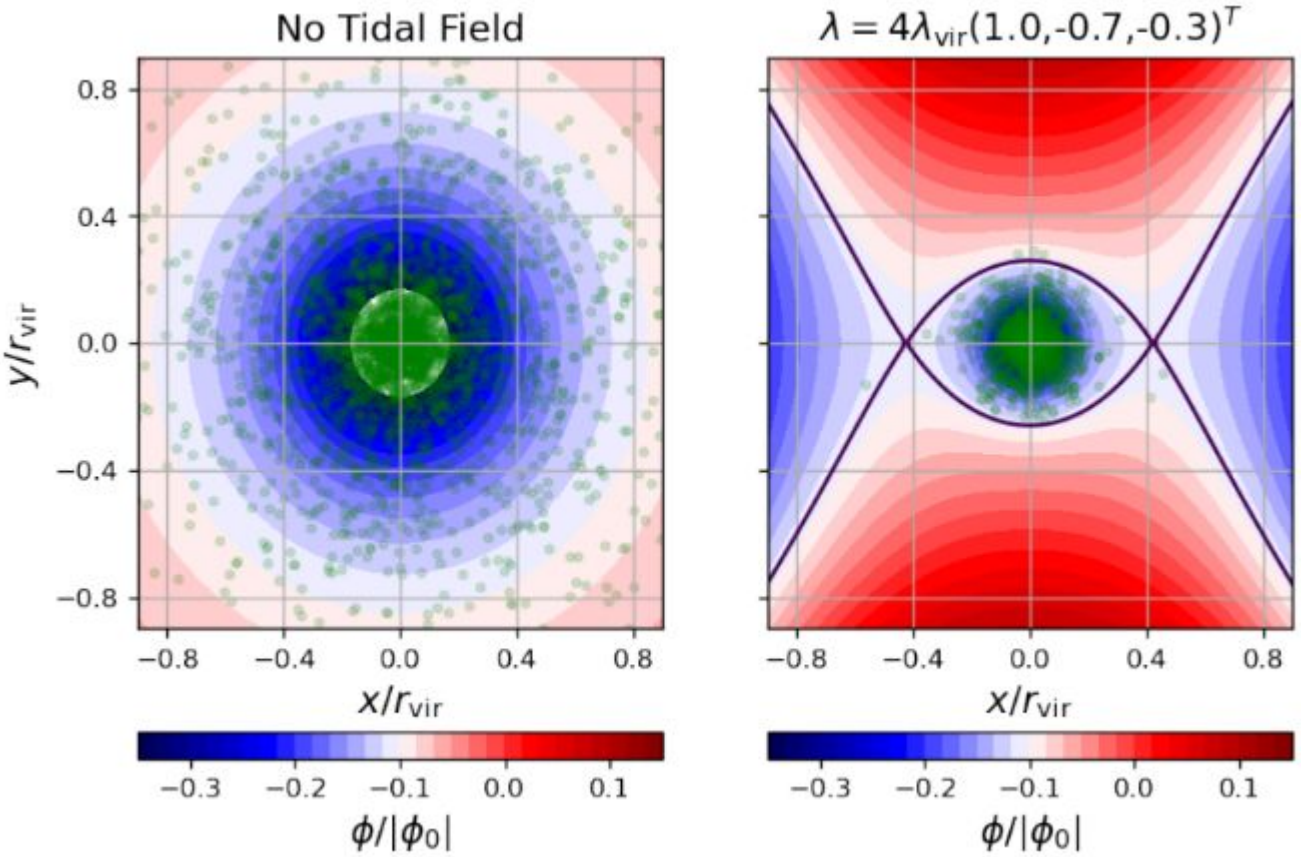
Tidal Stripping in the Adiabatic Limit

$$\phi(\vec{x}) = \phi_s(\vec{x}) - \frac{1}{2}\vec{x}\mathbf{T}(t)\vec{x}$$



Tidal Stripping in the Adiabatic Limit

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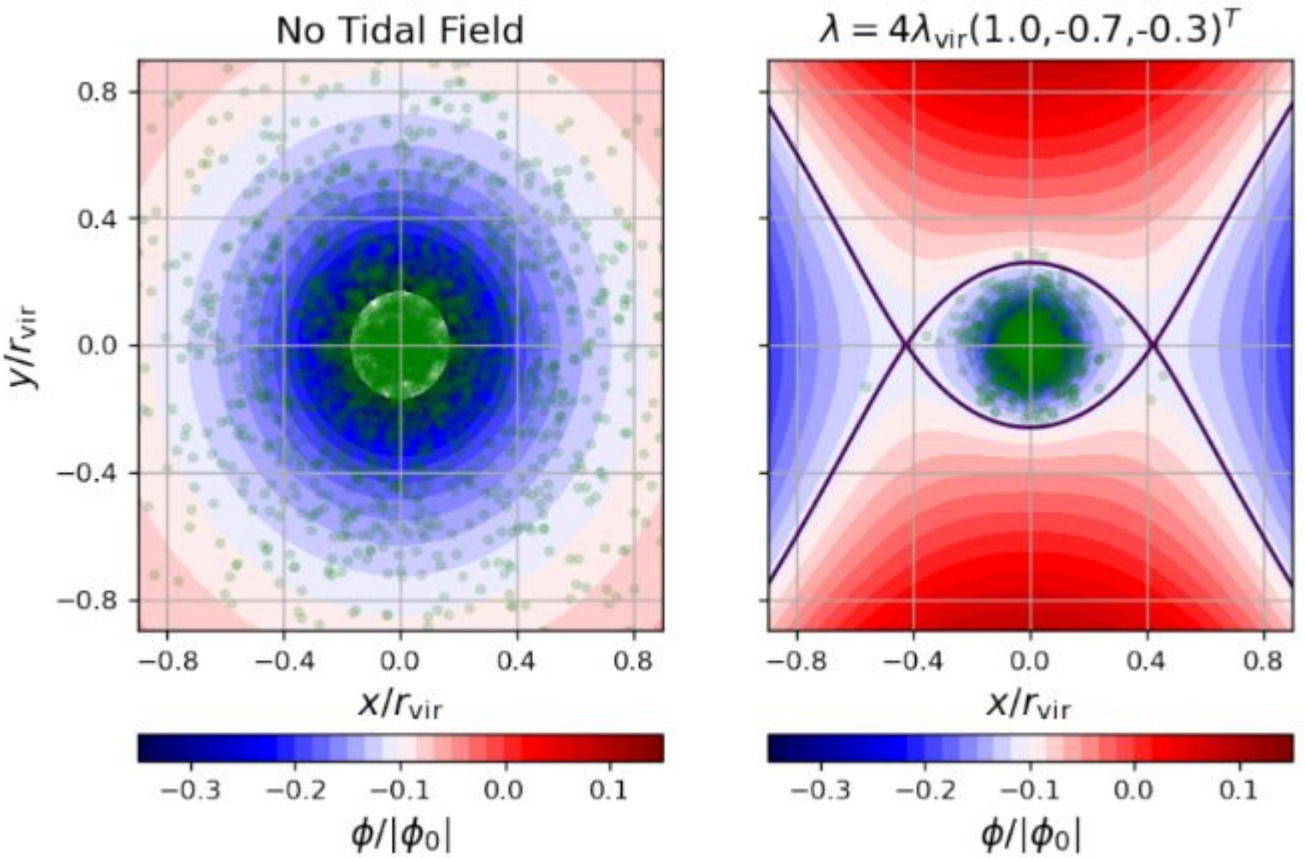


Energy truncation

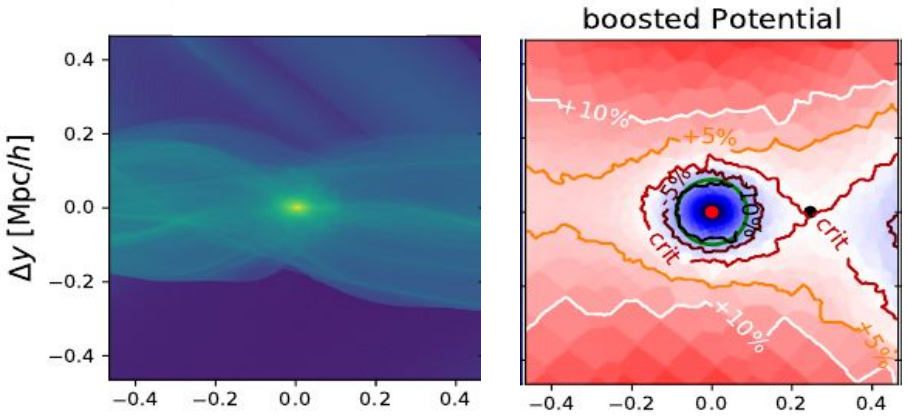
+

Internal Redistribution

Stücker et al. (in prep)

Ideas to think about

- **Theoretical:**
  - What is the boundary of a halo?
  - The Cosmic Web as a hierarchy of bound structures?
- **Potential Landscape in the outskirts of haloes**
  - Anisotropy of AGN Gas Ejection, Baryonification models
- **Properties of haloes**
  - Tidal Fields & Intrinsic Alignment
  - Bound & Unbound populations
  - Virial Ratios
- **Tidal Stripping (see Stücker et al. in prep)**
- **The Lagrangian Potential & The Formation of Structures**

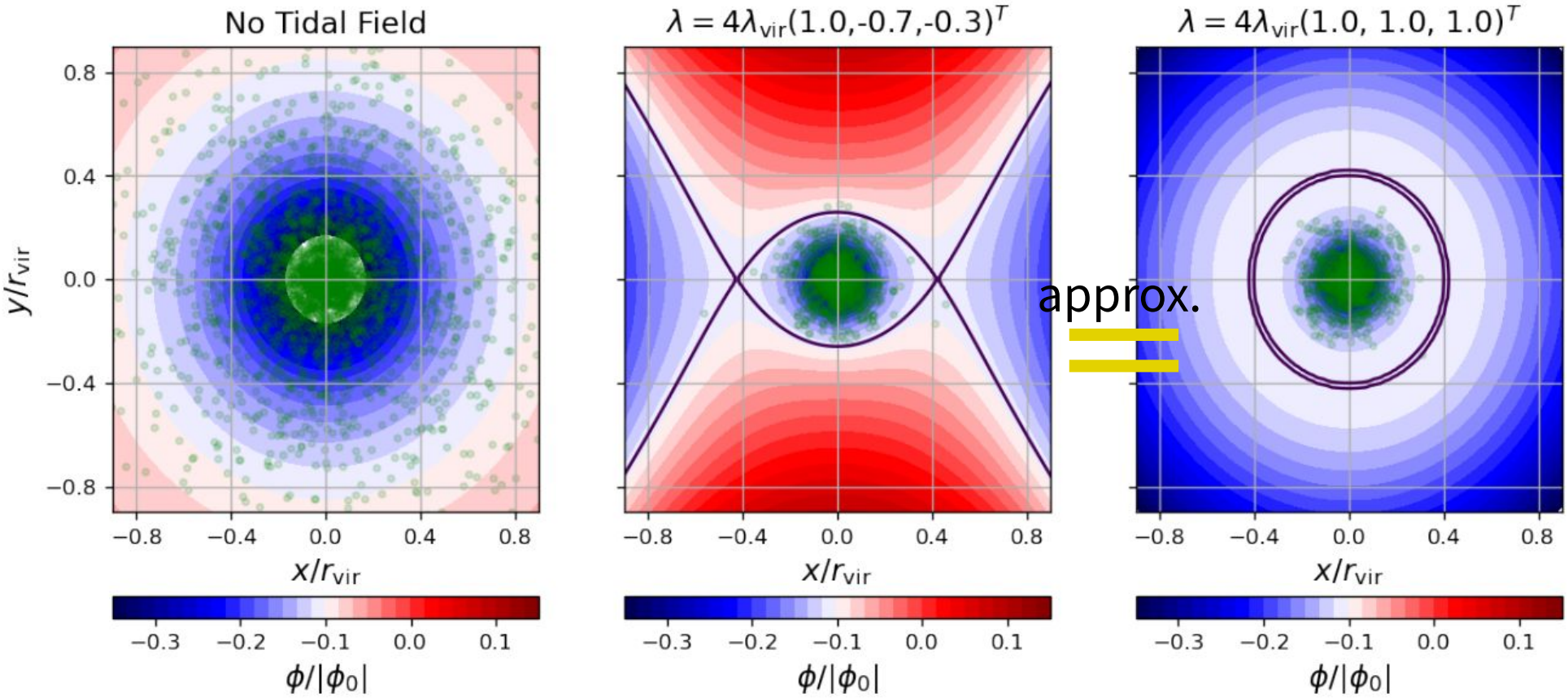


For more, see:
“The Boosted Potential”
Stücker, Busch & Angulo (2021)

Appendix

Tidal Stripping in the Adiabatic Limit

Analytic



Stücker et al. (in prep)

The Boosted Potential and the Cosmic Web

- The same binding notion can be applied to the cosmic web