

The Boosted Potential

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Cosmology from Home



Sheet + Release

This visualization shows a network of blue filaments representing the cosmic web. A prominent filament runs diagonally from the top-left to the bottom-right. A bright, glowing orange-red galaxy cluster is located in the lower-left corner. The background is a gradient of light blue and white.

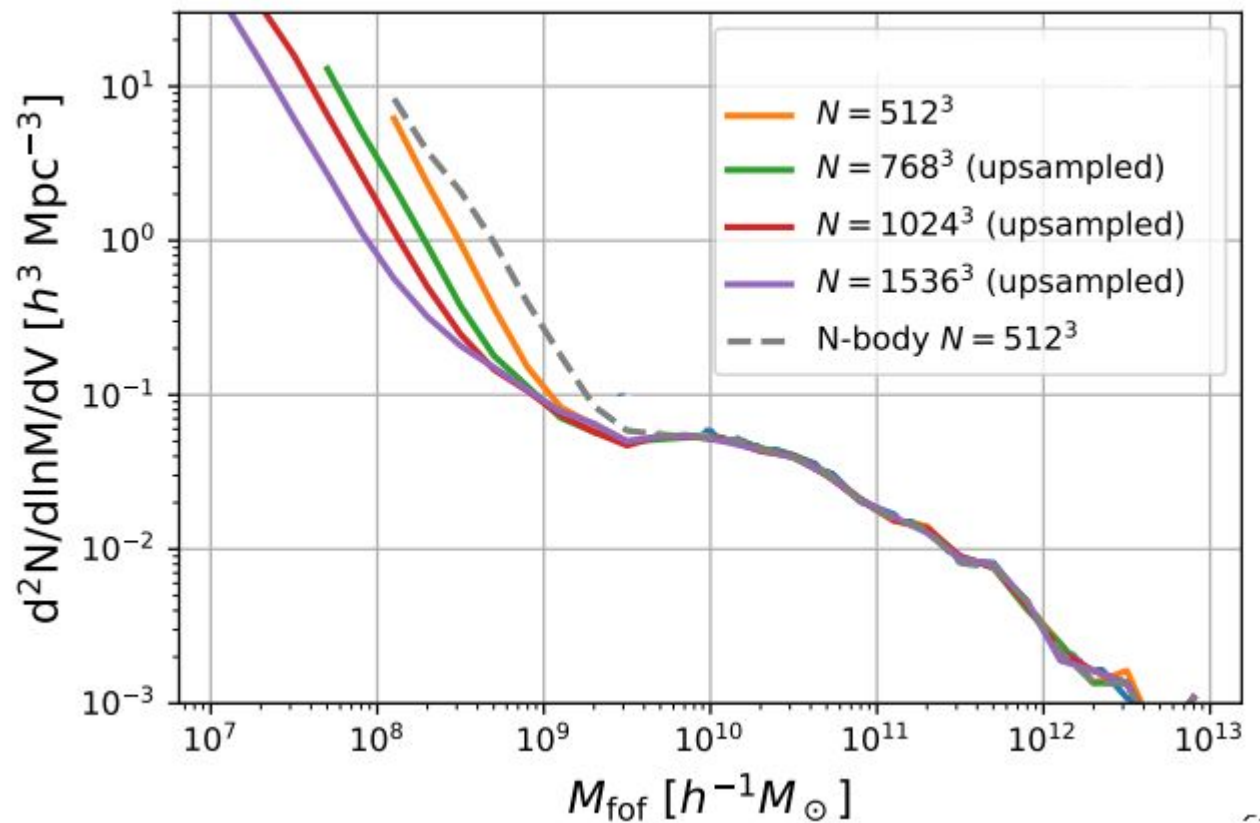


N-body

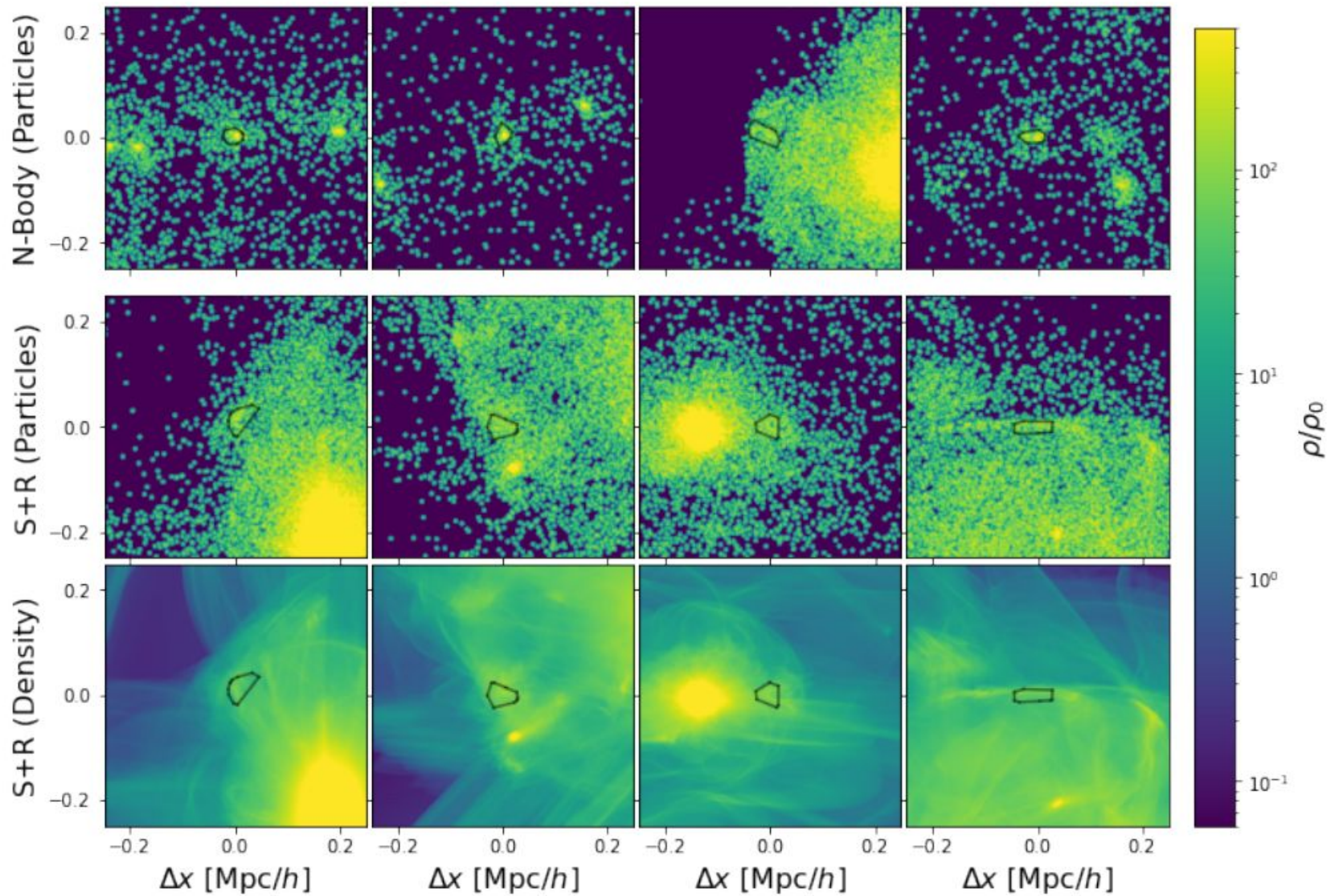
This visualization shows the same cosmic web structure as the top panel, but with a dense field of small blue dots representing individual particles. The filamentary structure and the bright orange-red galaxy cluster in the lower-left corner are clearly visible against the background of particles.

Stücker et al (2020, 2021)

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

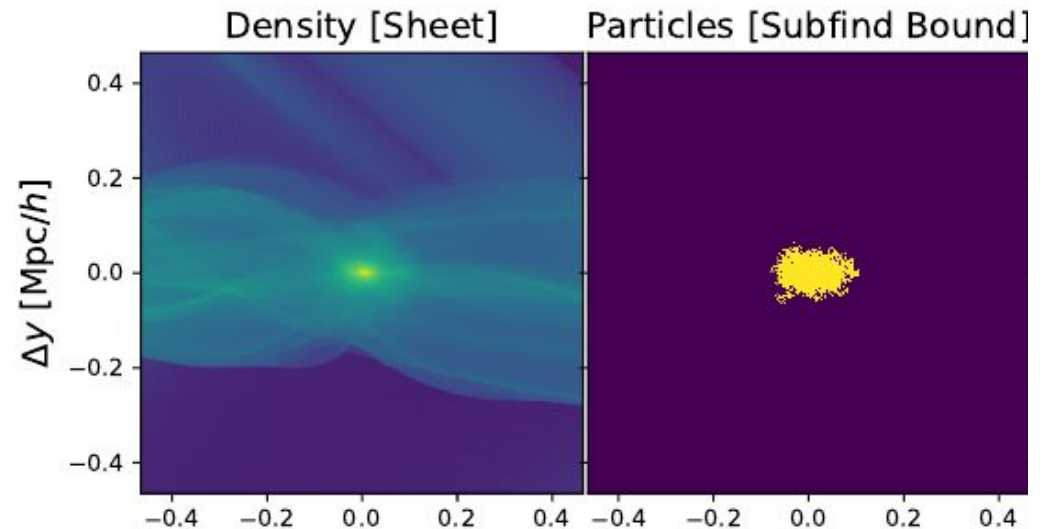


Typical objects with $M = 5e8 M_{\text{sol}}$

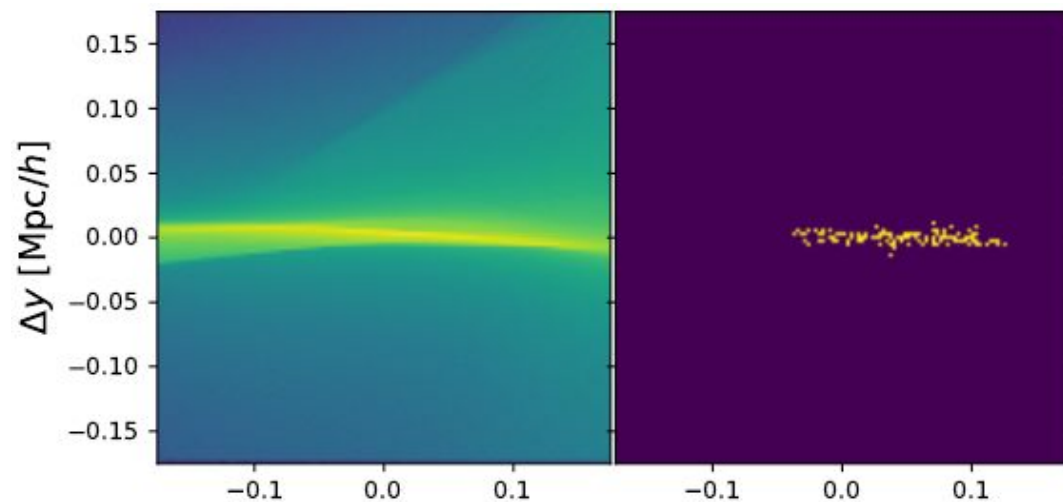


A problem with halo finders (in Warm DM simulations)

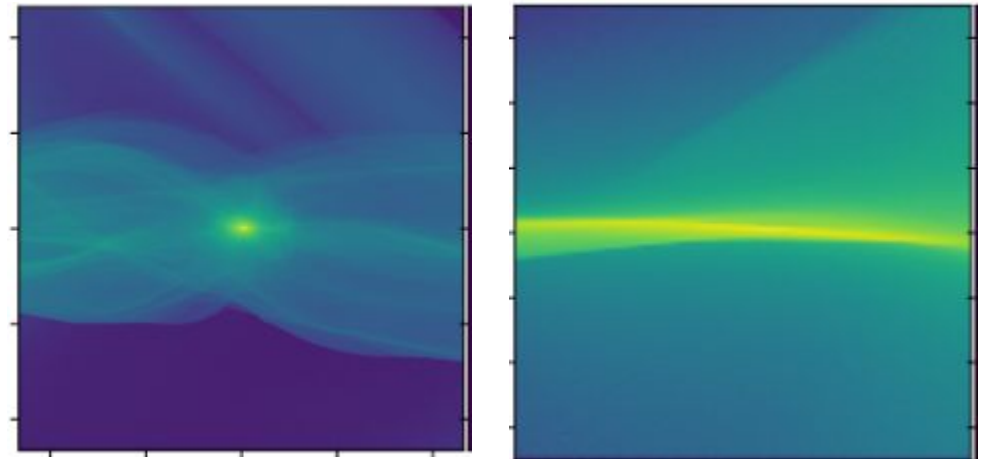
- **Normal Halo:**



- **Misidentified Halo:**



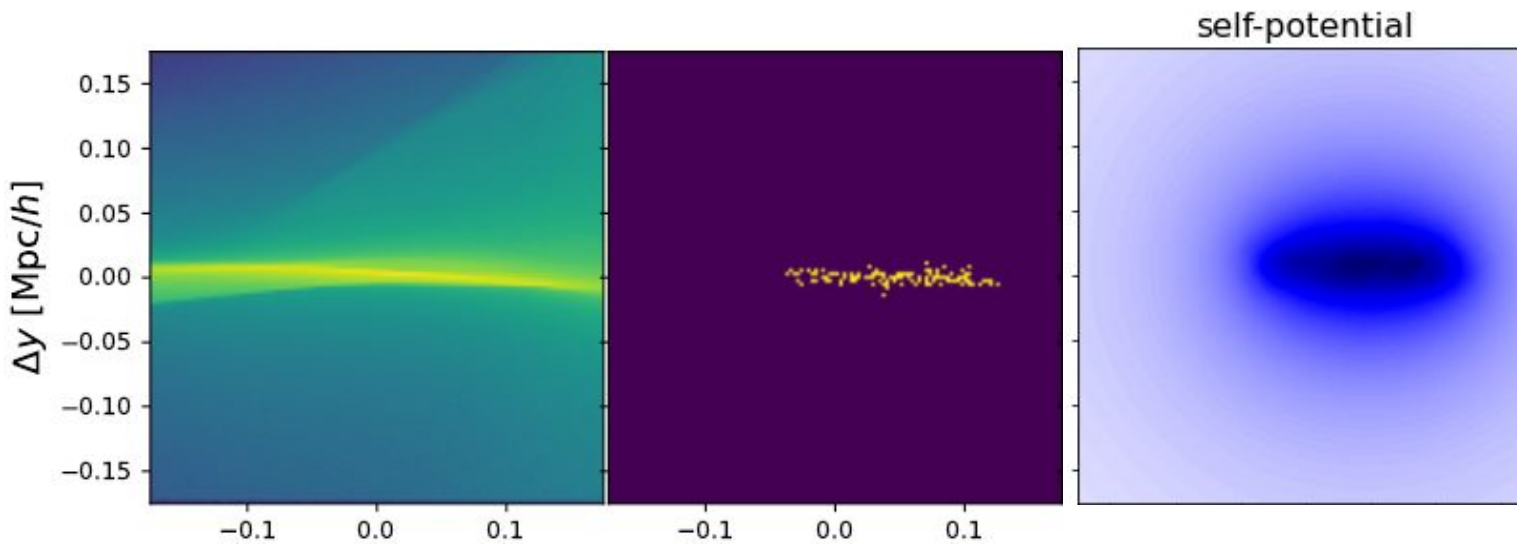
What is a Halo?



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



The self-potential Binding Check

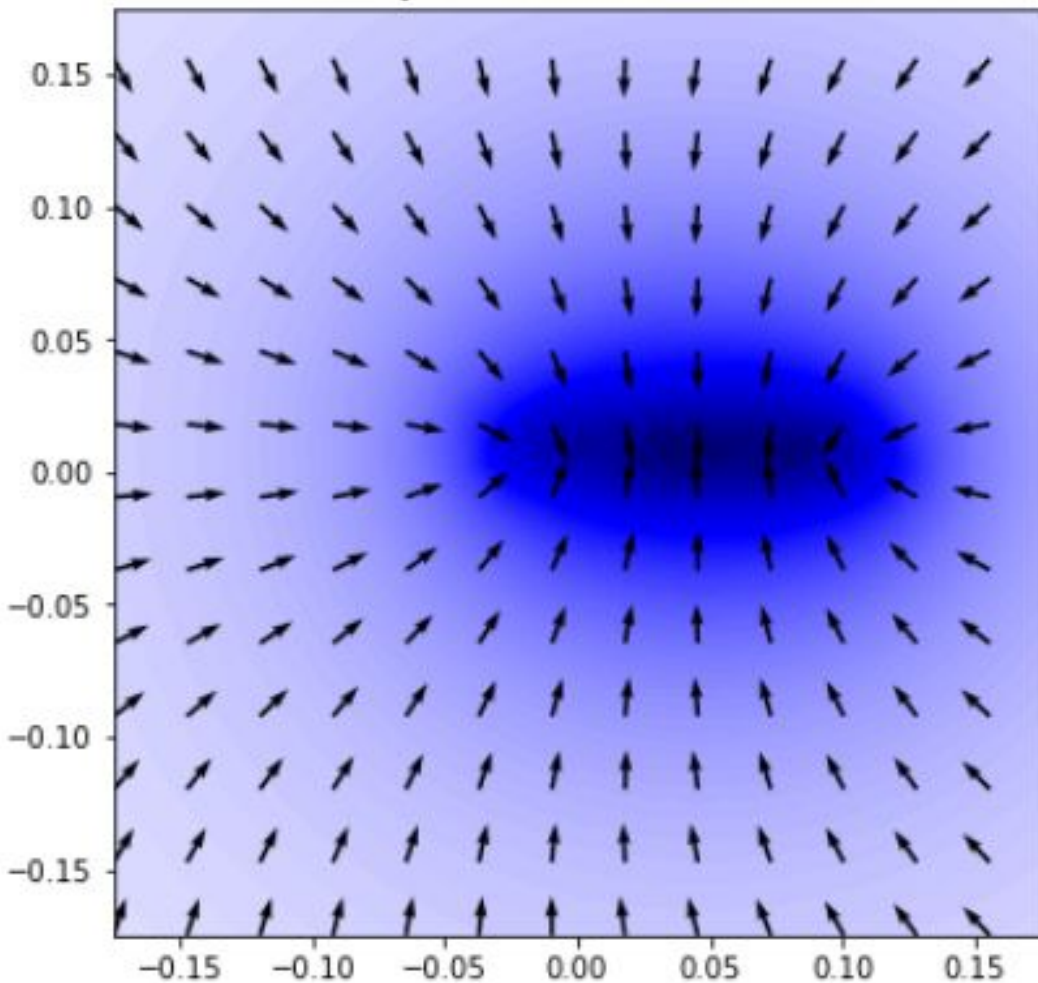


• Subfind Binding Check

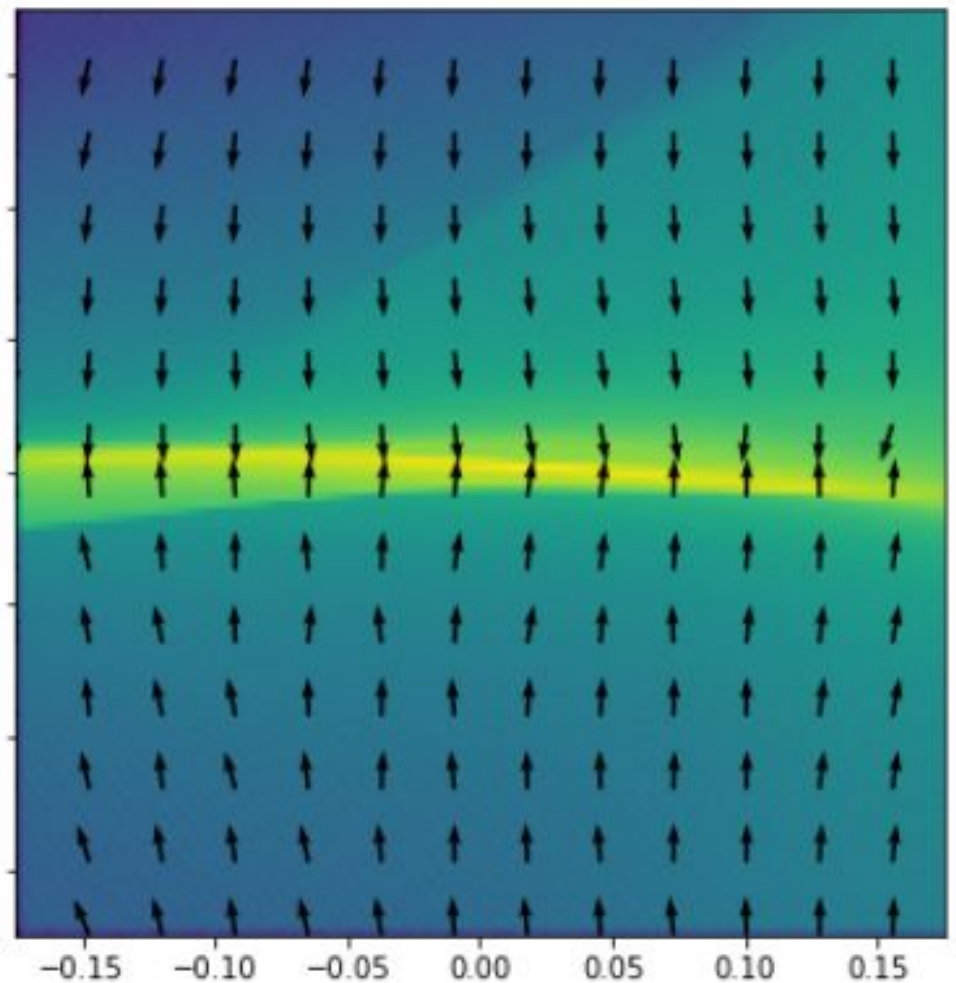


The self-potential Binding Check

self-potential and -force



actual force

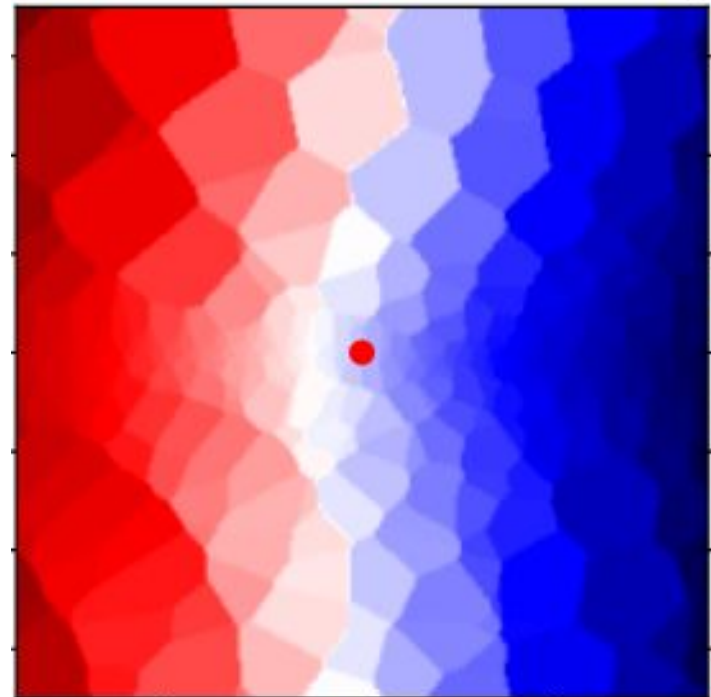
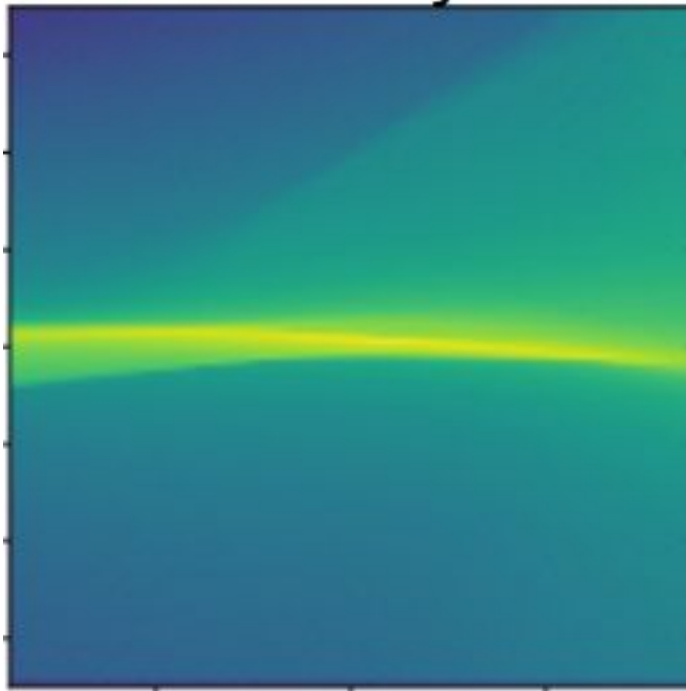


The self-potential Binding Check

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

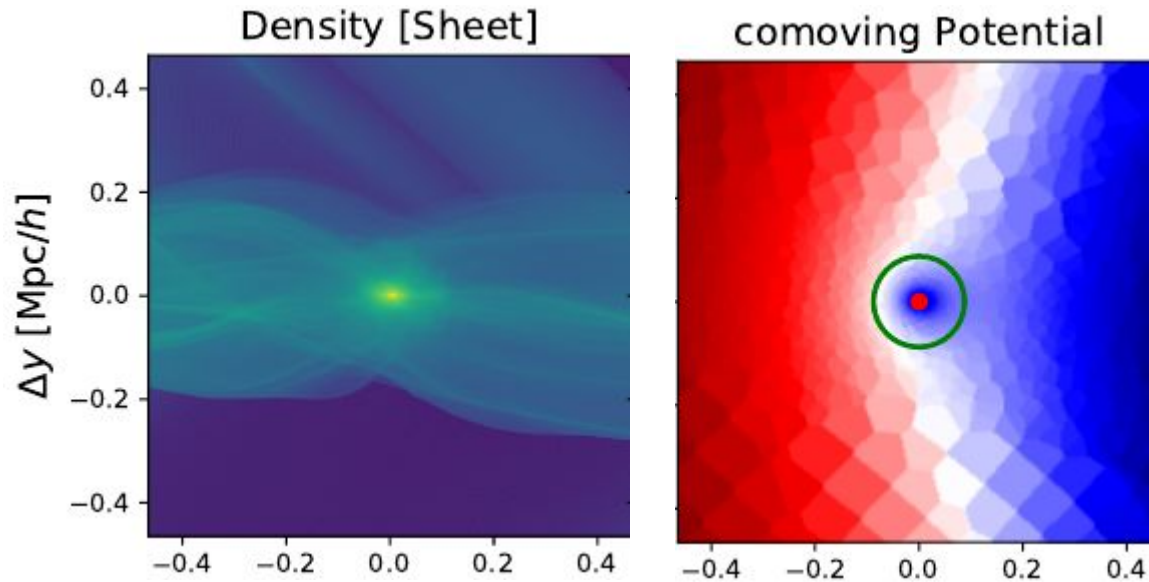
=> Use the **global potential** field ?

The global potential



The potential (?!)

The global Potential



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

An accelerated frame of reference

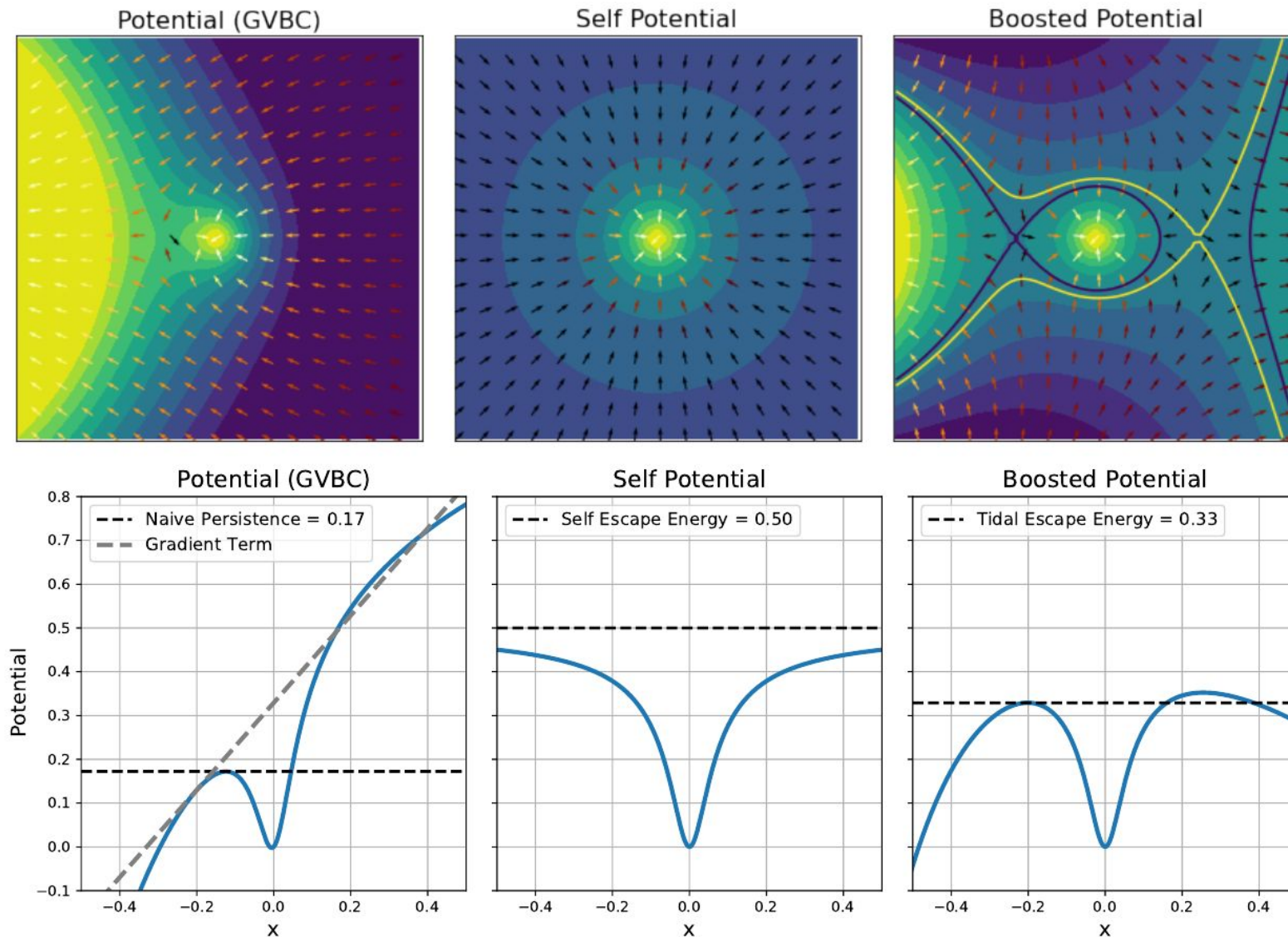
- **Switch to an accelerated frame:**

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

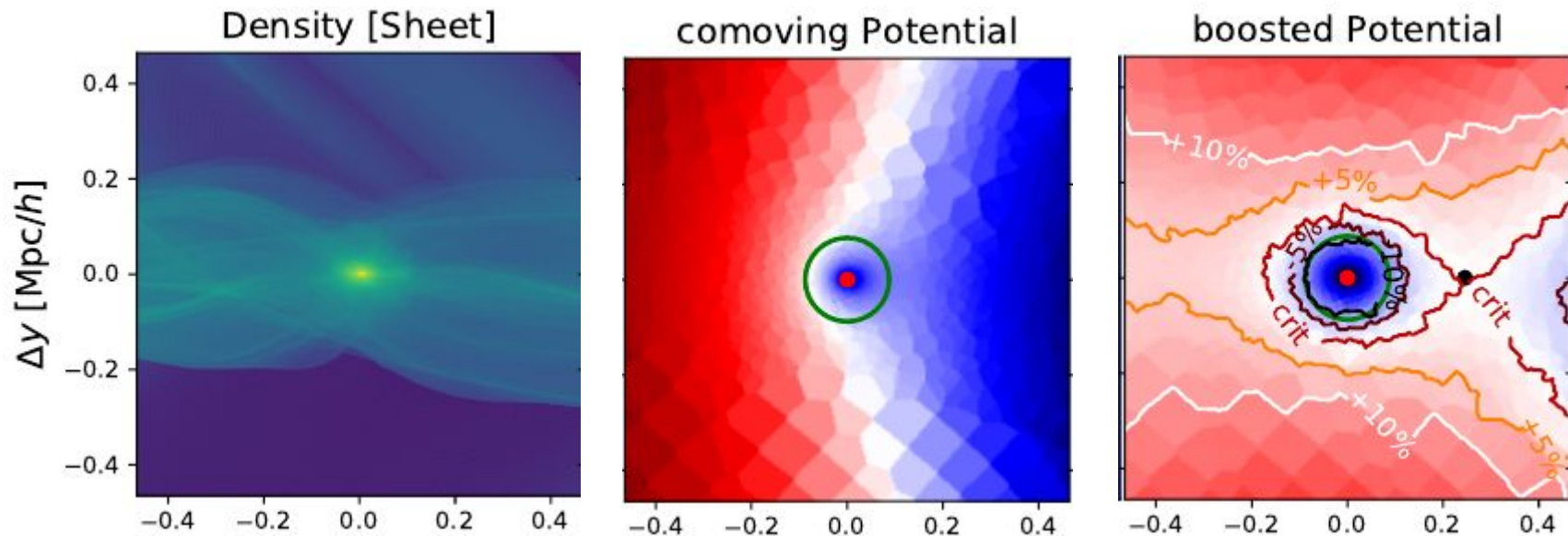
- **Introduces an apparent force**
= global gradient in the potential

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

The boosted Potential



The boosted Potential

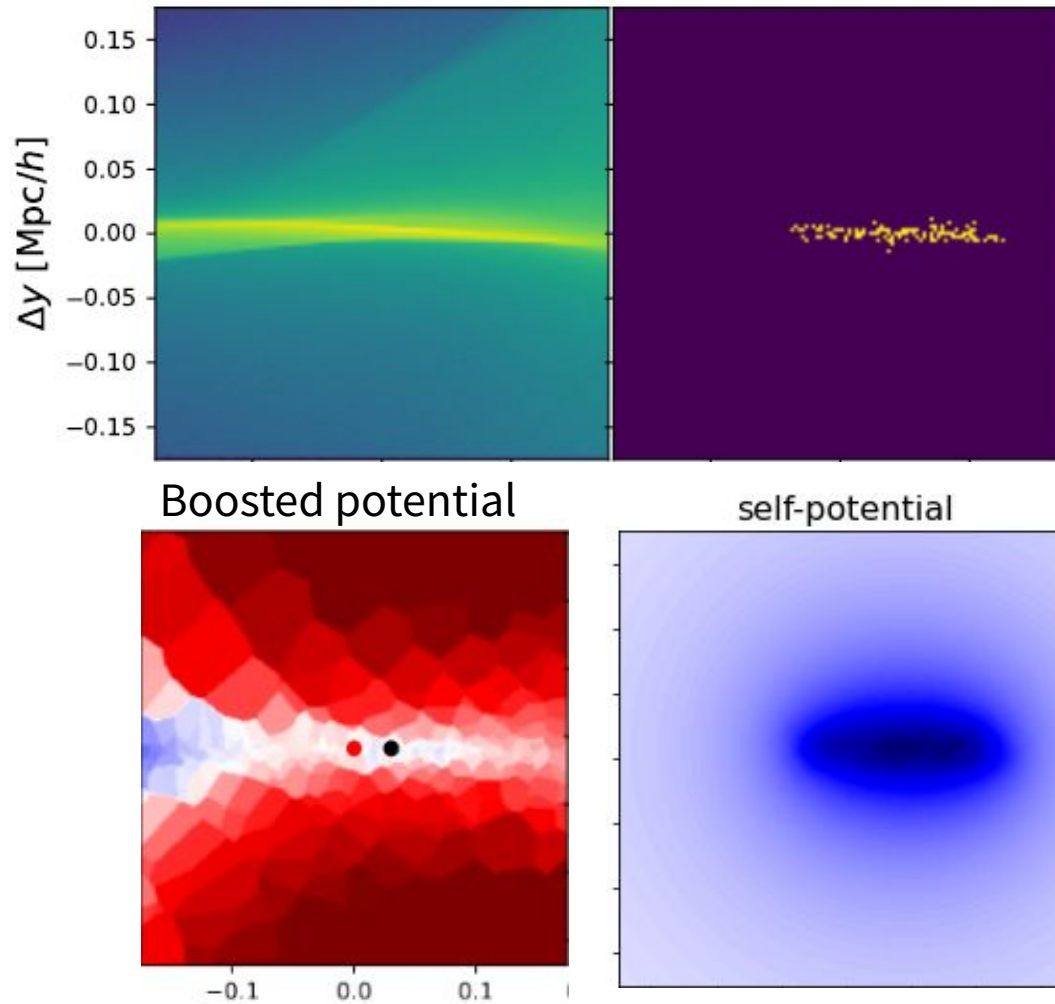


- **Switching to the accelerated frame removes the global gradient**

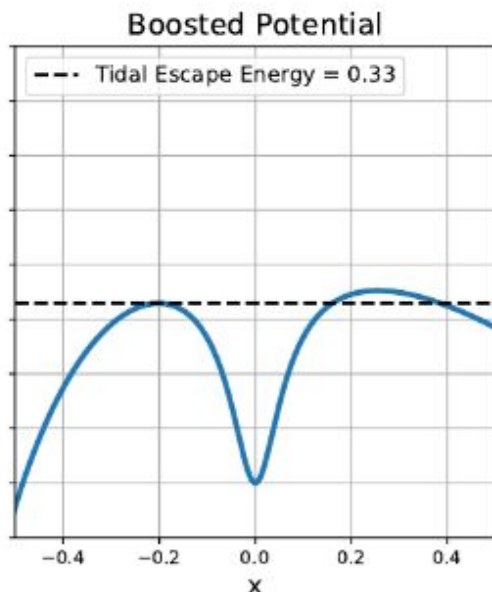
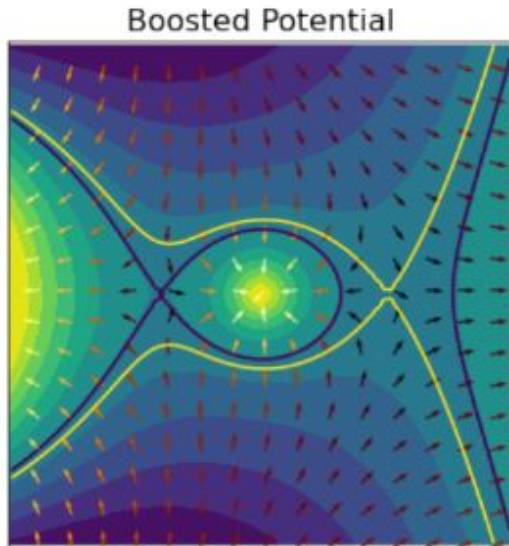
$$\phi_{\text{boost}}(\mathbf{x}) = \phi(\mathbf{x}) + \mathbf{a}_0 \cdot \mathbf{x}.$$

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

The boosted potential binding check

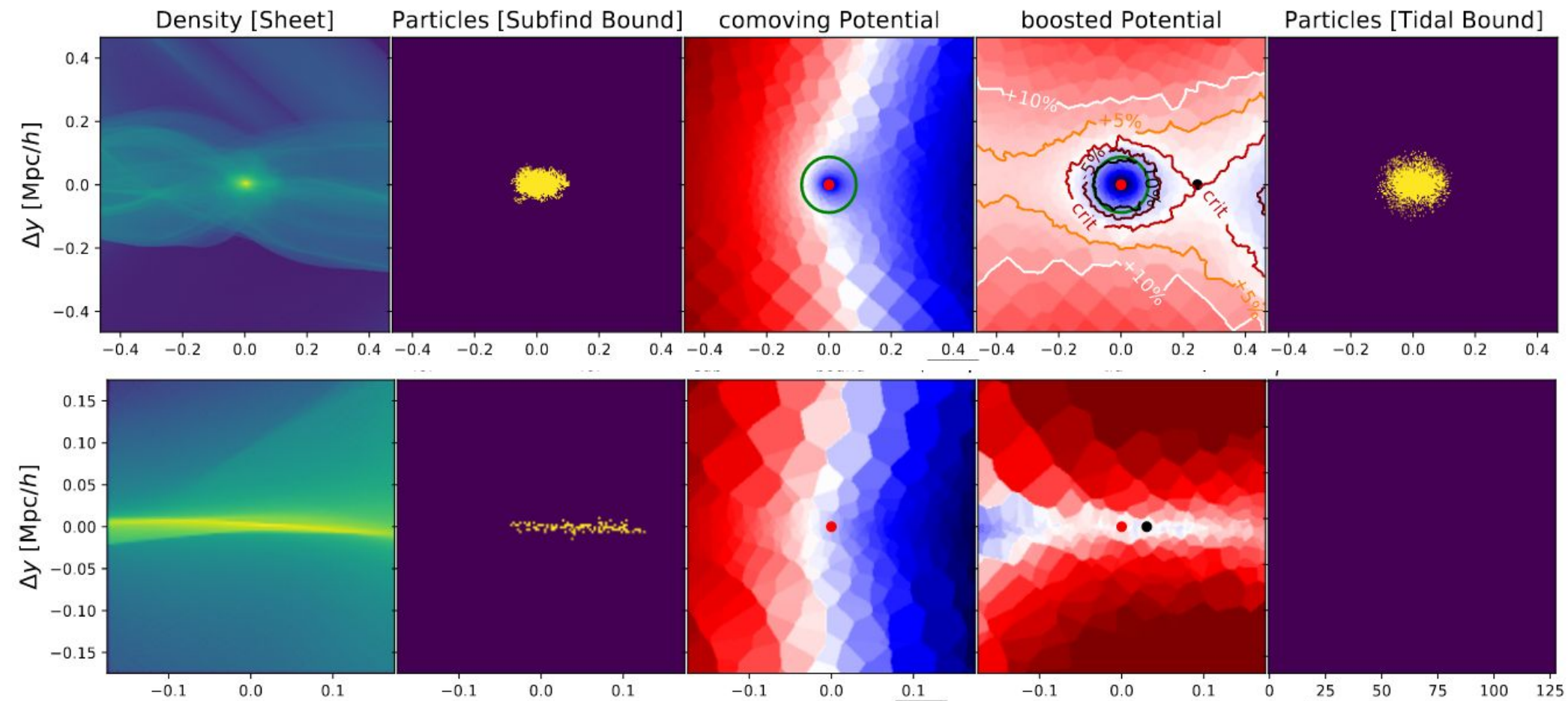


The boosted potential binding check

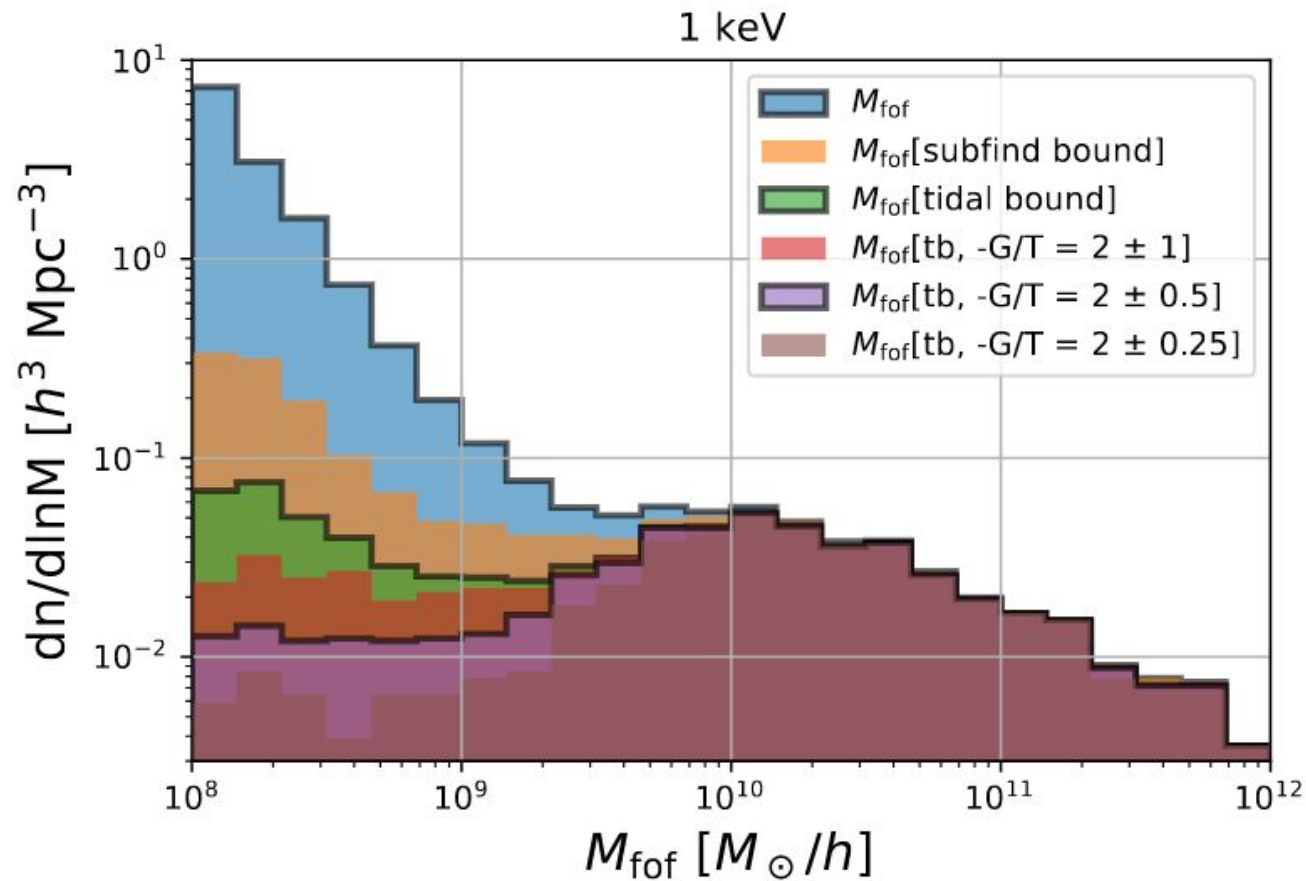


- Critical energy level Φ_{saddle}
- The critical contour defines the **tidal boundary**
- Particles with $E > \Phi_{saddle}$ can **escape** the object
- Particles with $E < \Phi_{saddle}$ are **bound**

The boosted potential binding check

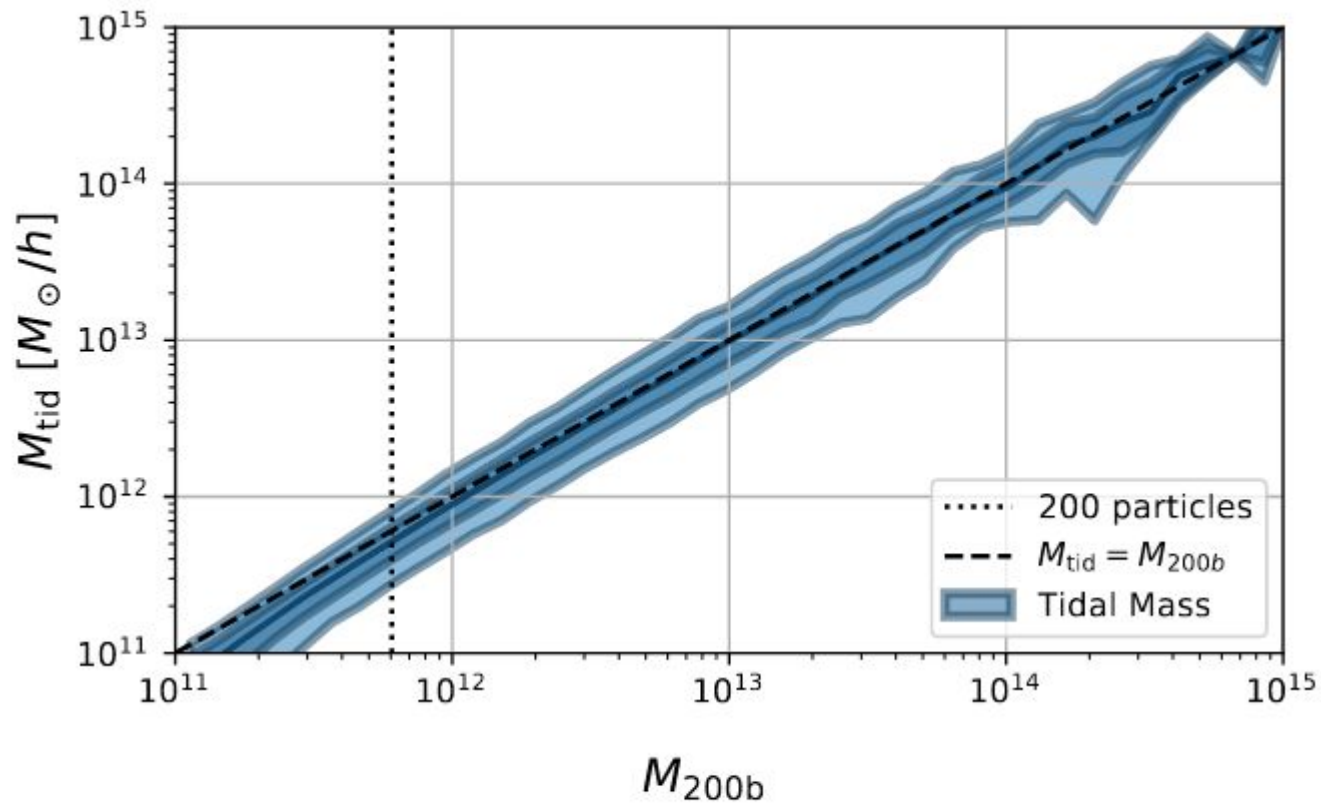


WDM Haloes at small masses



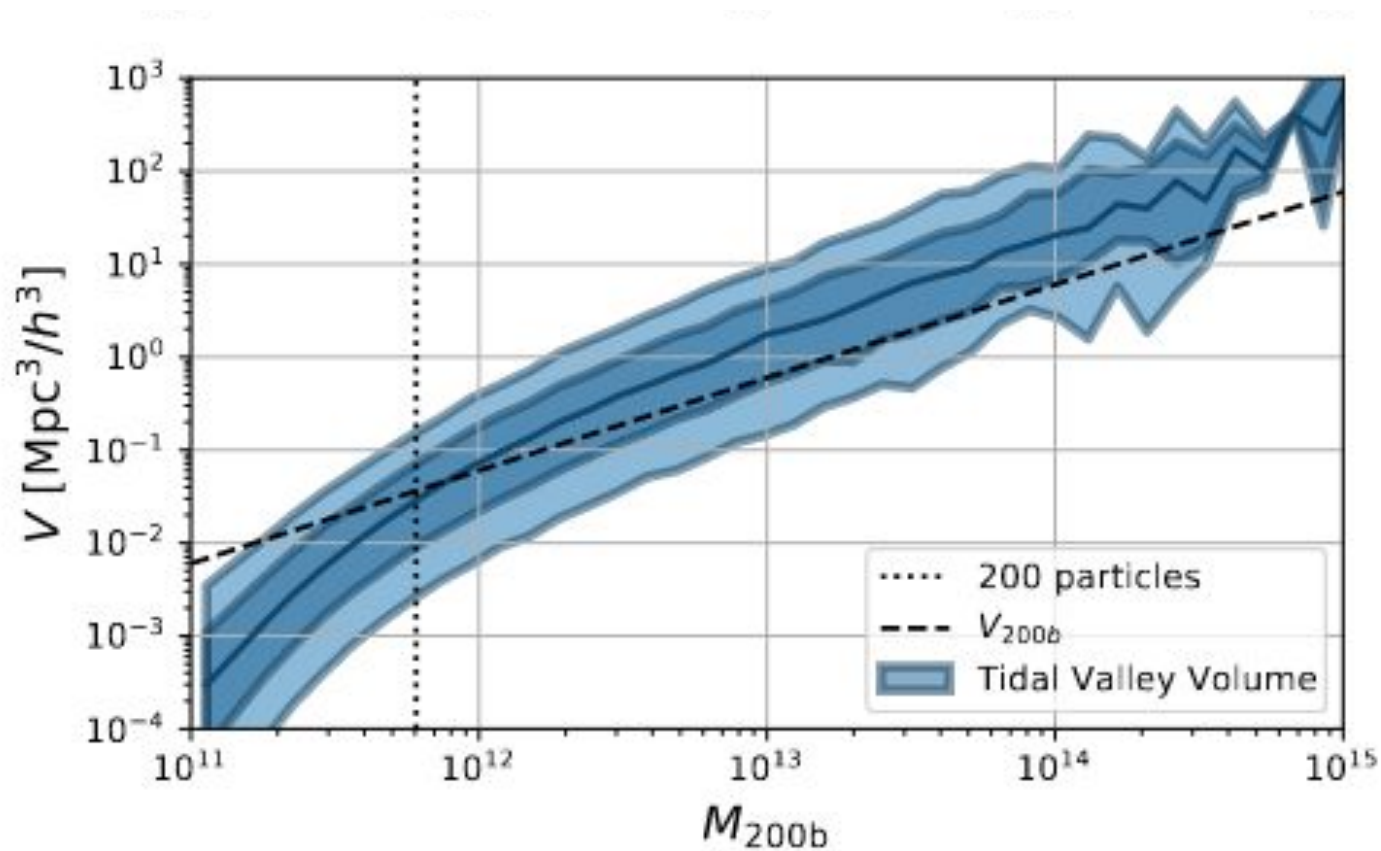
Stücker et al. (2021)

The “Tidal Mass”

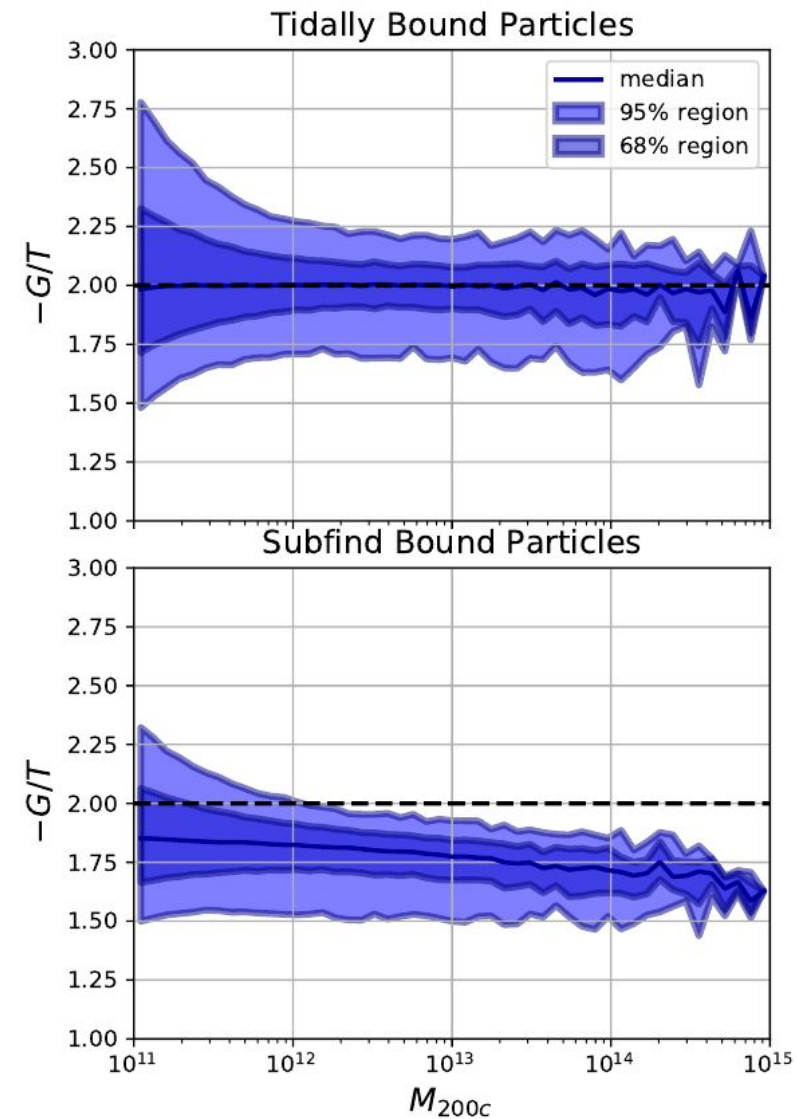


(CDM simulations)

The “Tidal Boundary”



The Virial Theorem and the Binding Check



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

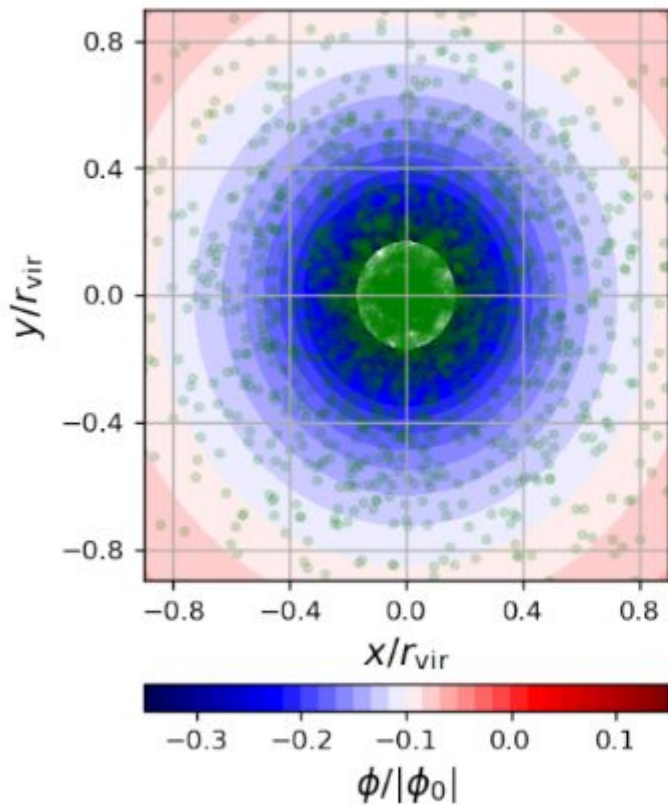
$$T := \frac{1}{2} \langle (v - \langle v \rangle)^2 \rangle$$

$$-G / T = 2$$

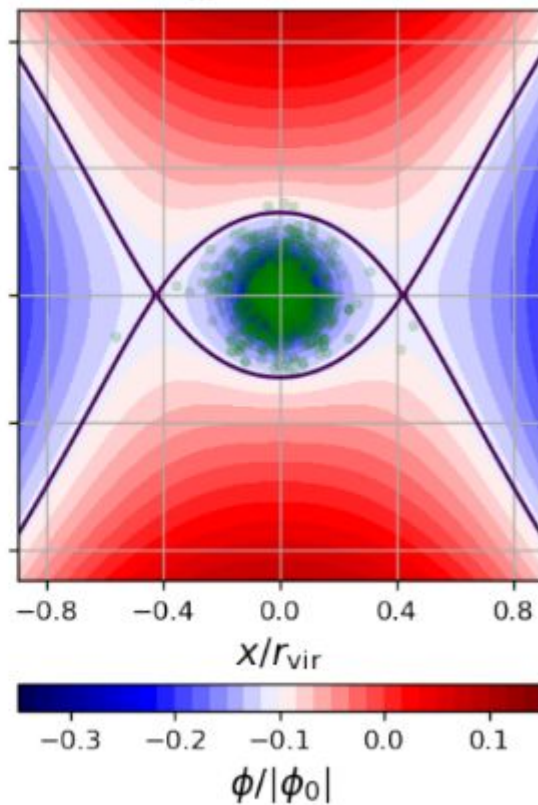
Tidal Stripping in the Adiabatic Limit

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

No Tidal Field



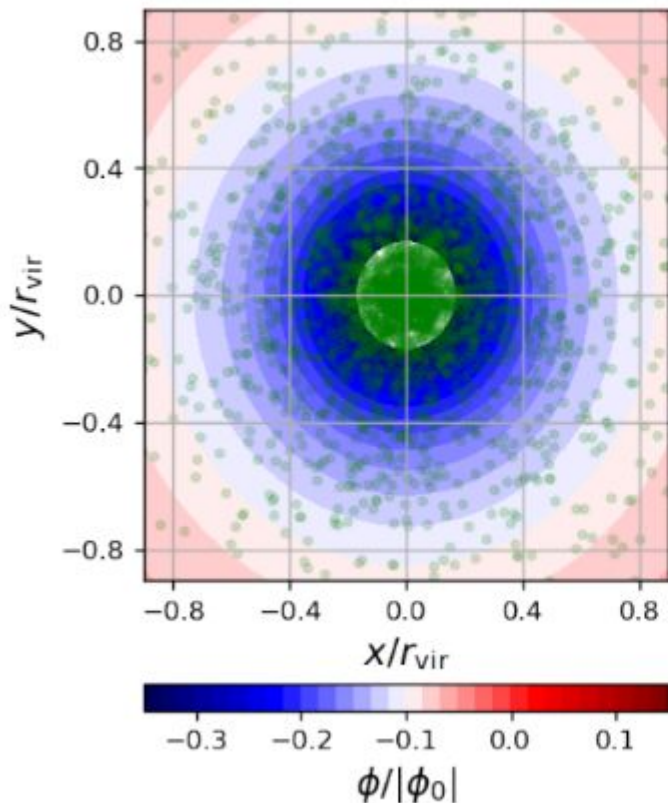
$\lambda = 4\lambda_{\text{vir}}(1.0, -0.7, -0.3)^T$



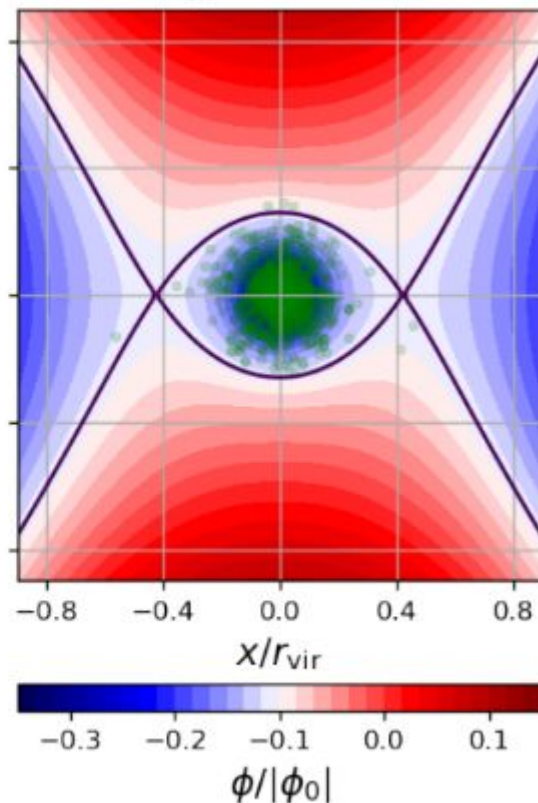
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No Tidal Field



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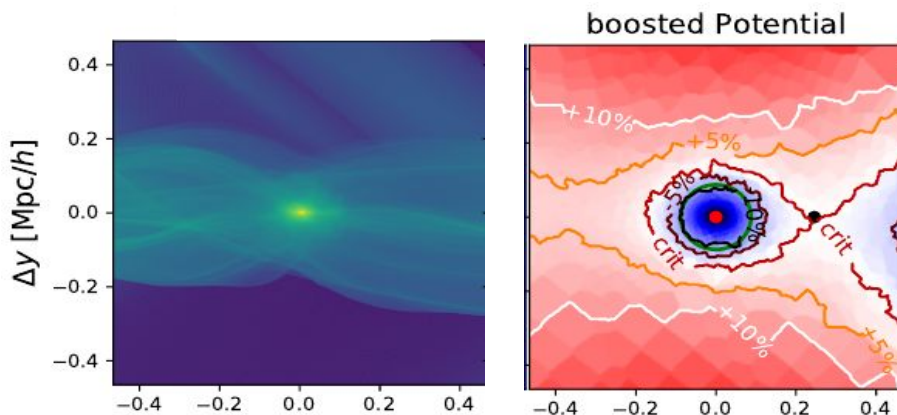


Energy truncation
+
Internal Redistribution

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**

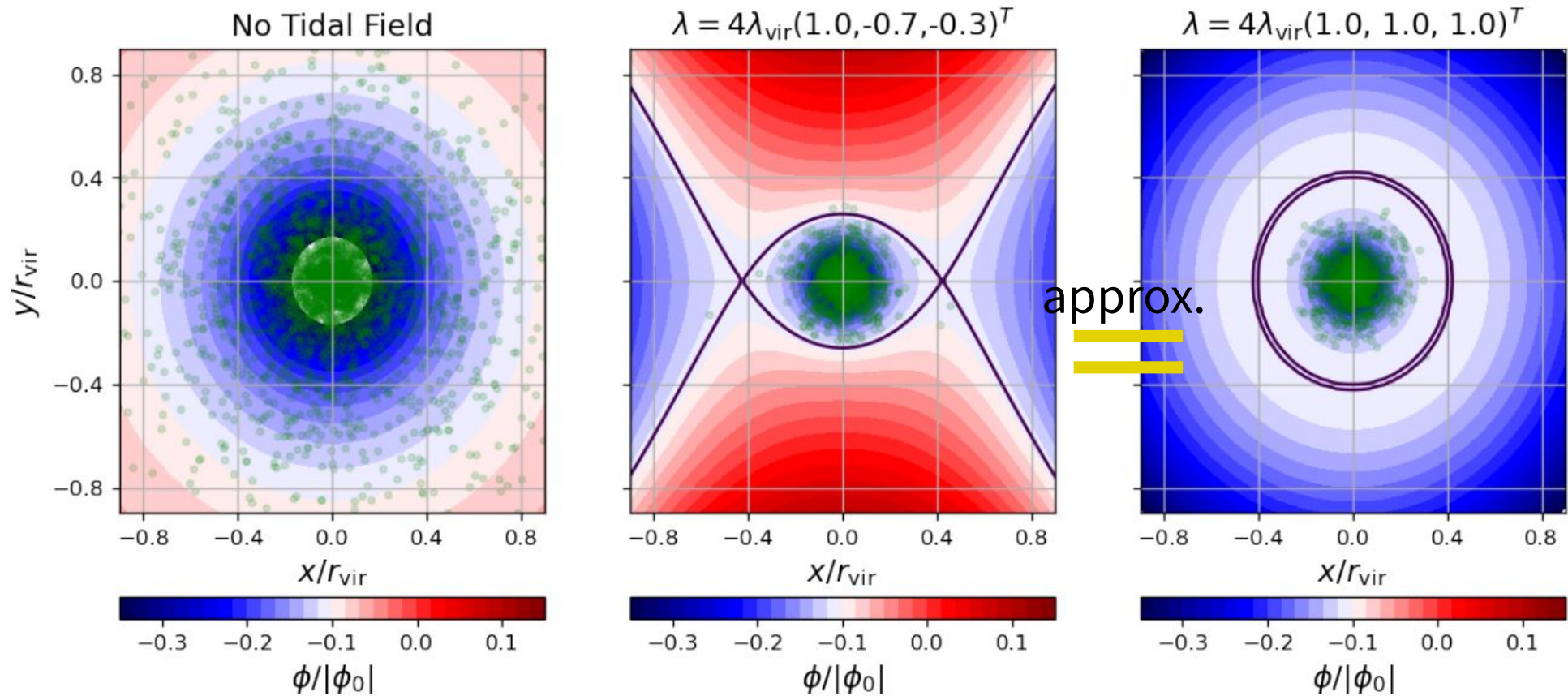


For more, see:
“**The Boosted Potential**”
Stücker, Busch & Angulo (2021)

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

