

Simulating the dark Universe: The role of baryons



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Alexander Hobbs, George Lake, Romain Teyssier



Outline

1. “DM-only” simulations.
2. The trouble with Warm Dark Matter.
3. The role of baryon physics on small scales.
4. The future | The Agora project.
5. Conclusions.

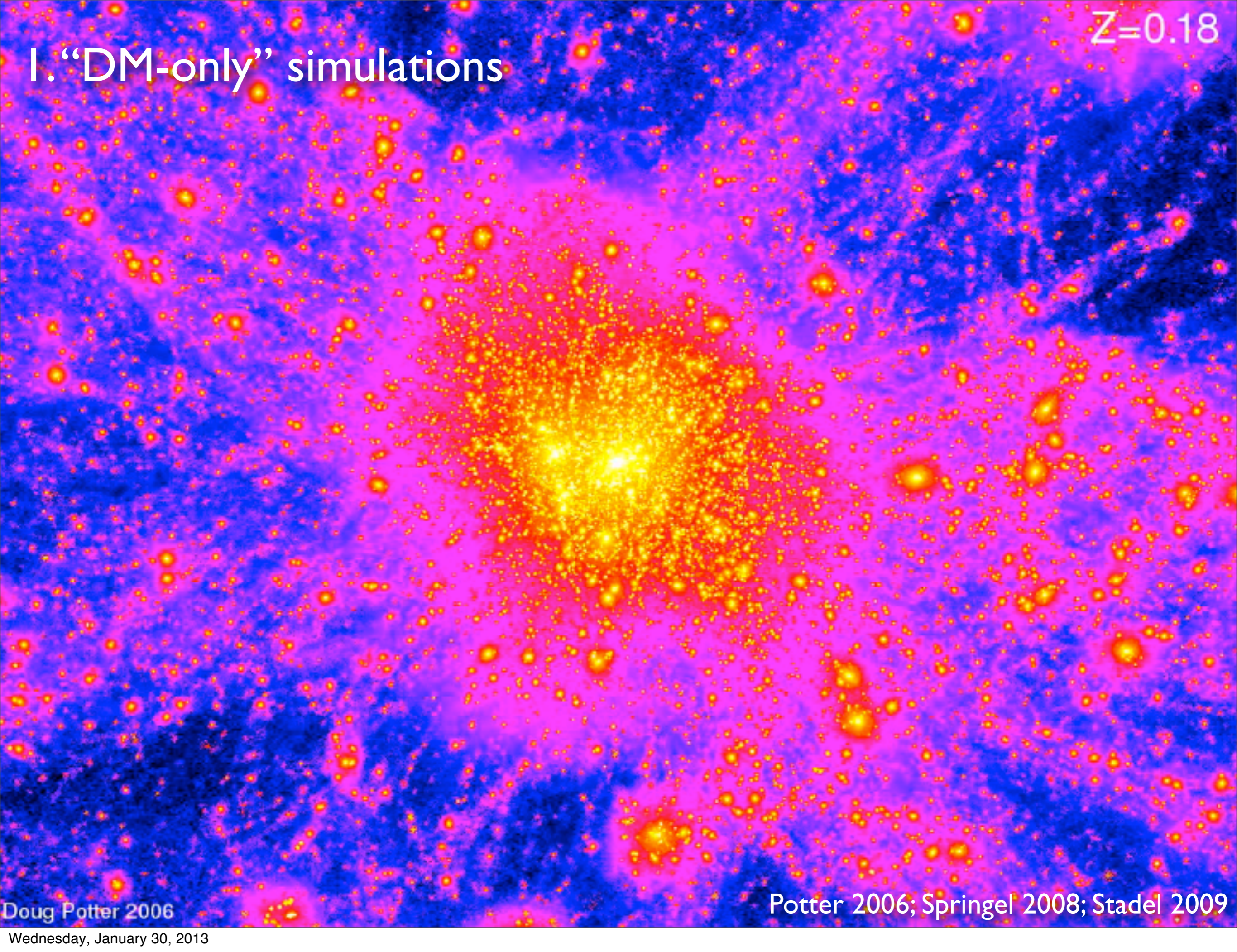
I. “DM-only” simulations

Potter 2006; Springel 2008; Stadel 2009

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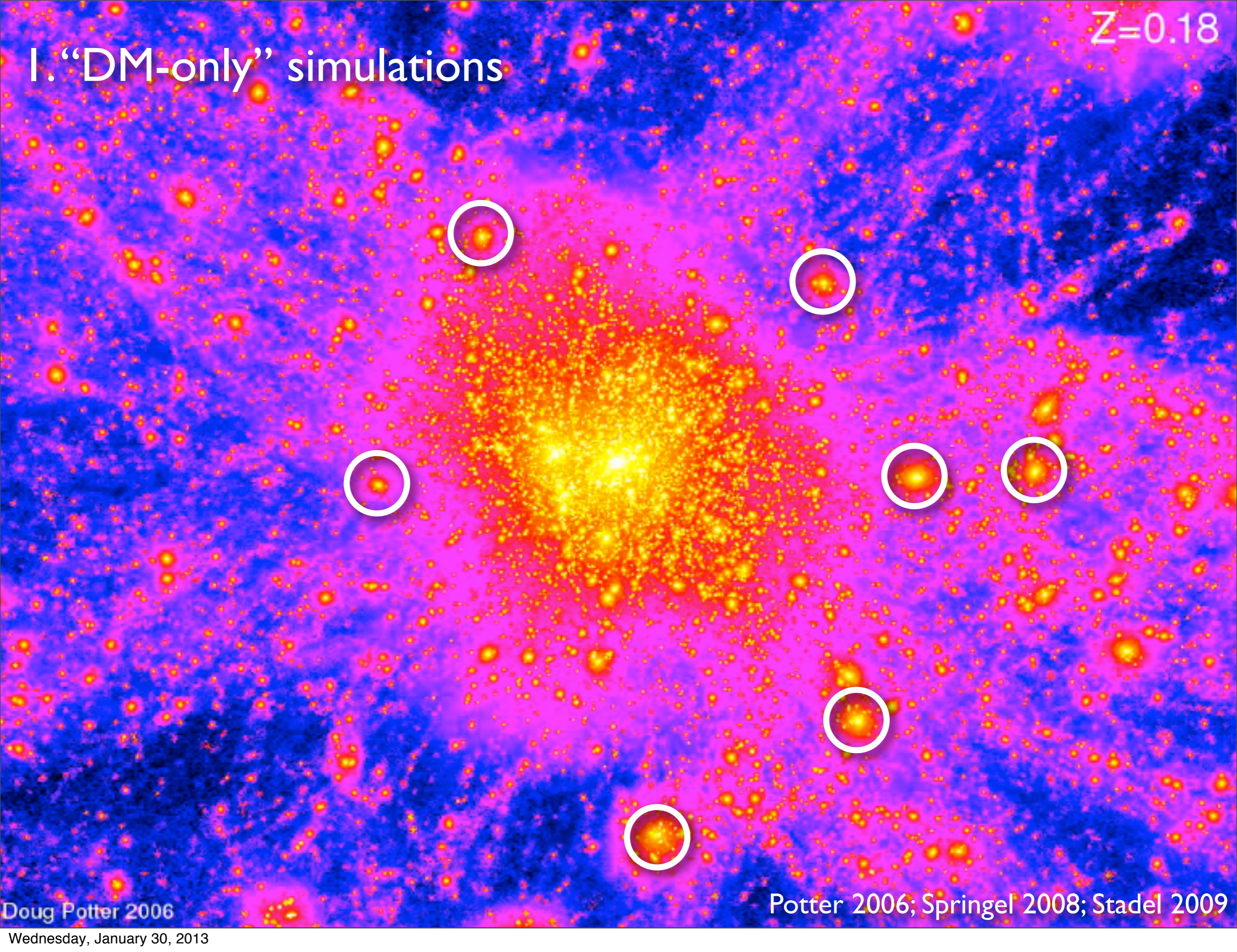
$Z=0.18$

I. "DM-only" simulations



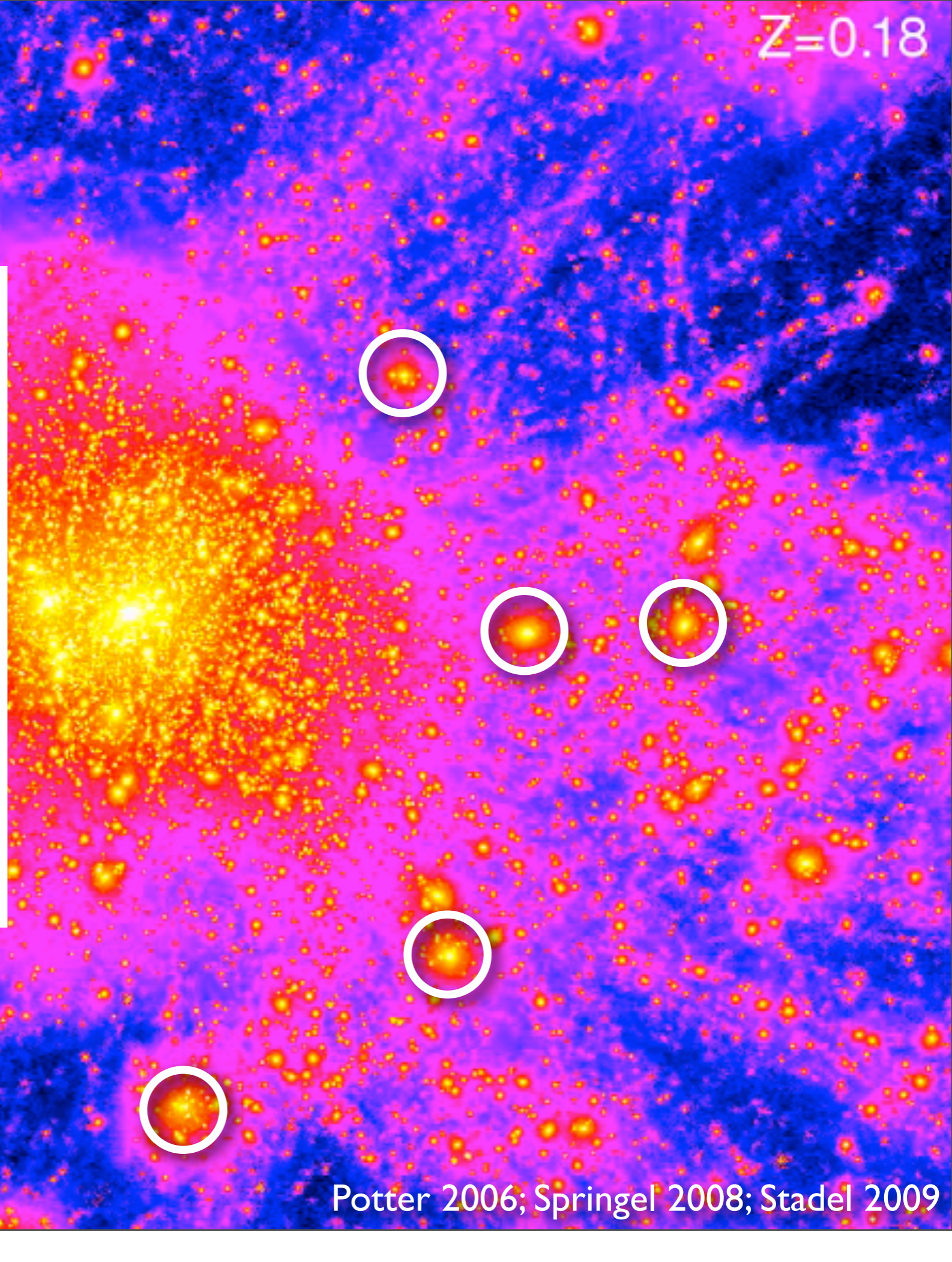
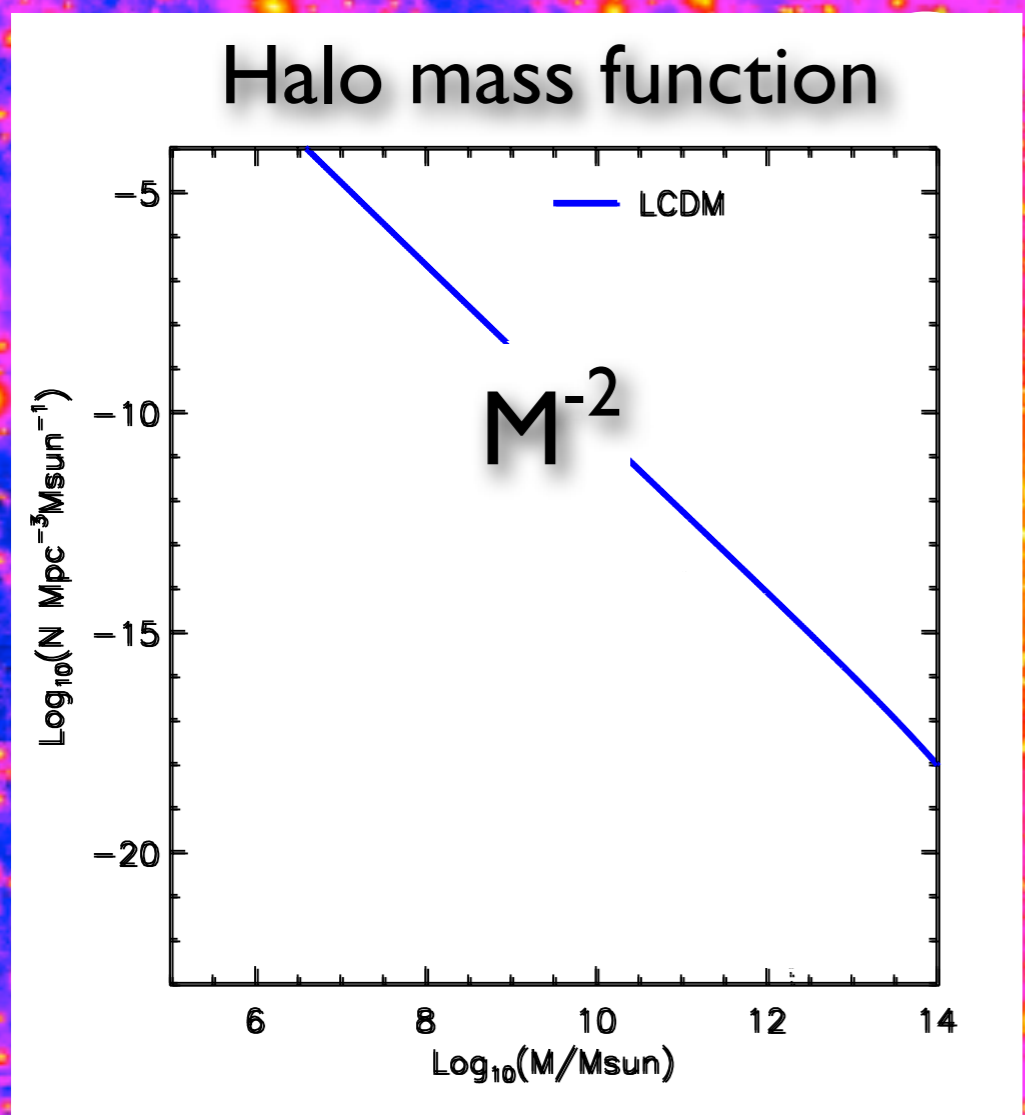
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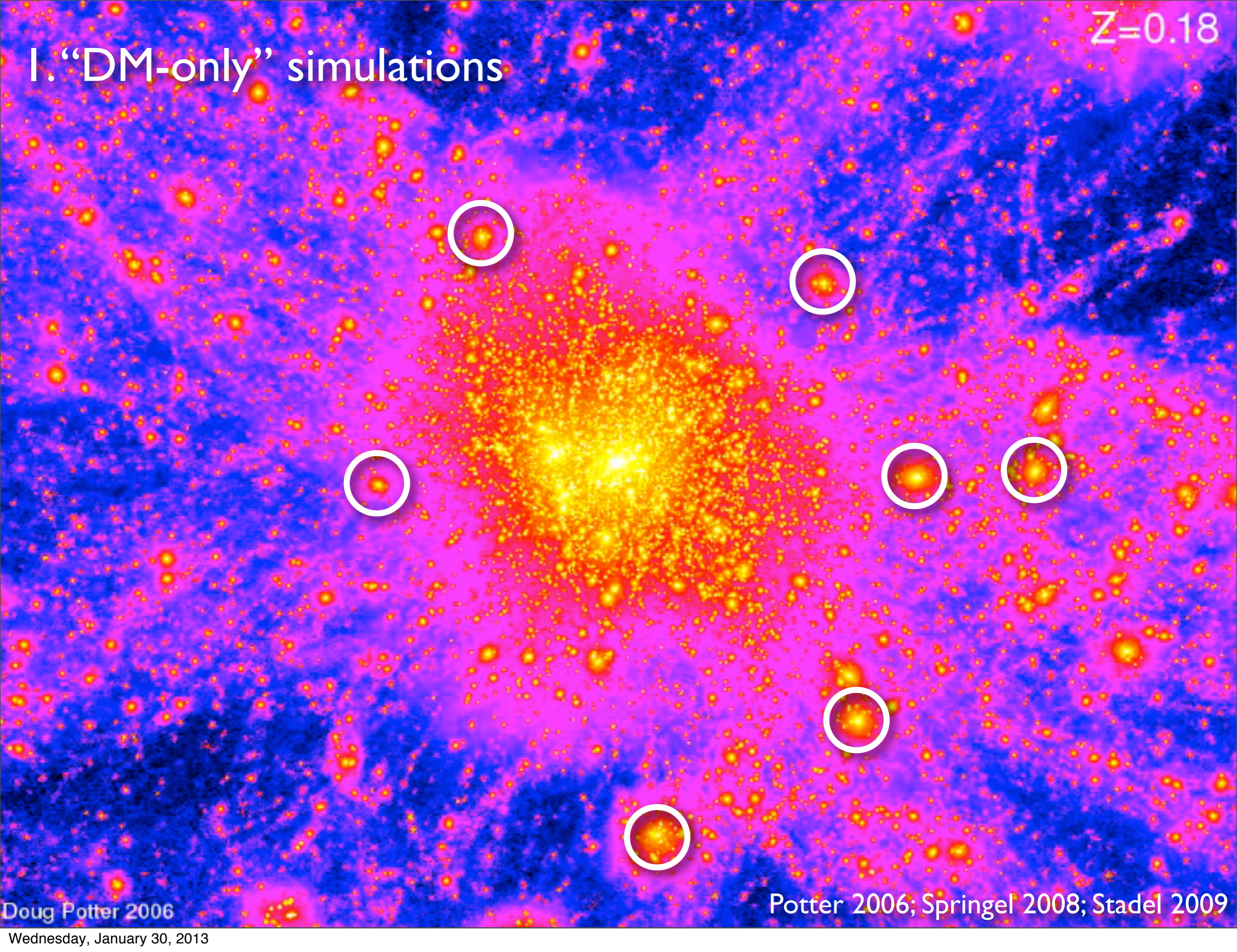
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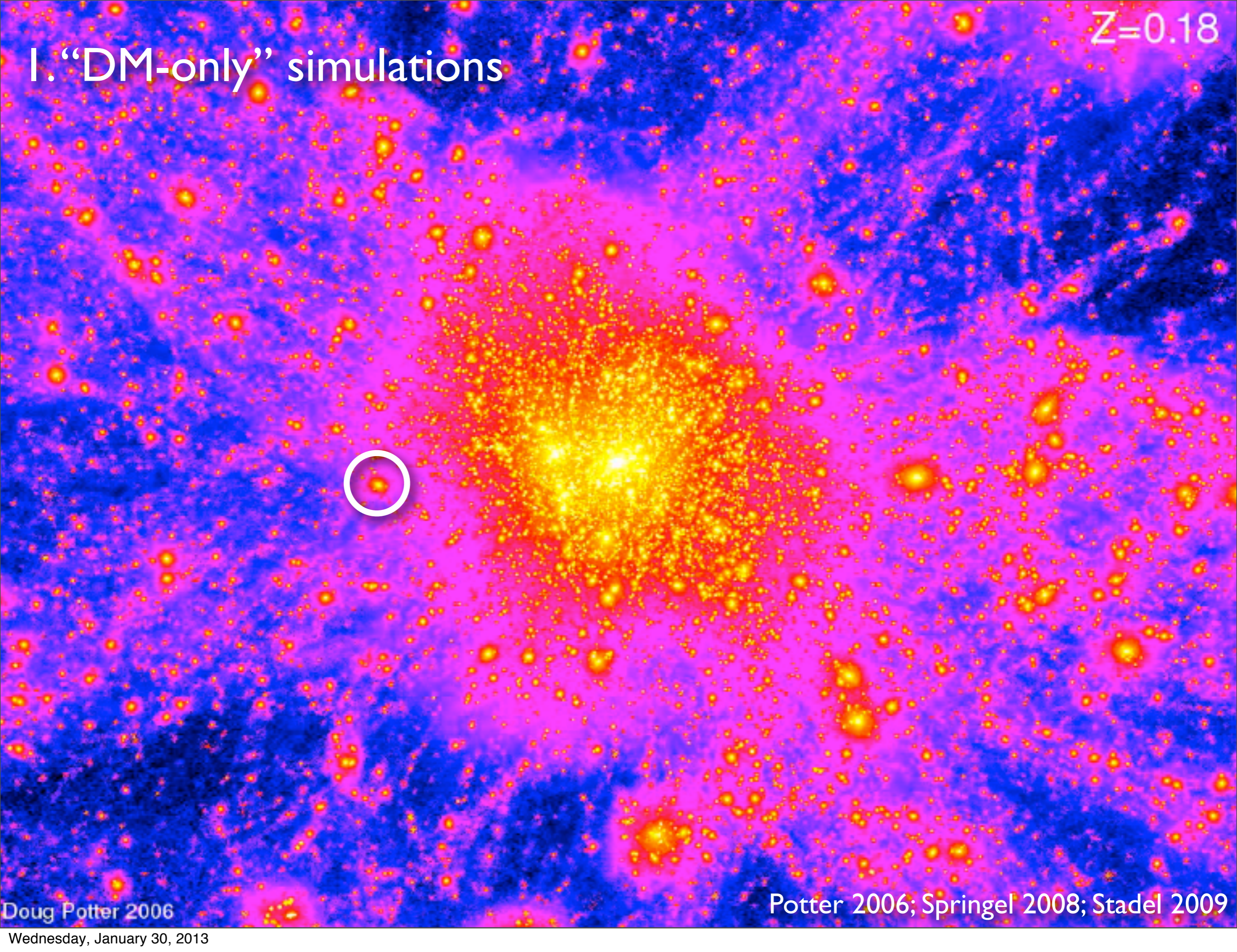
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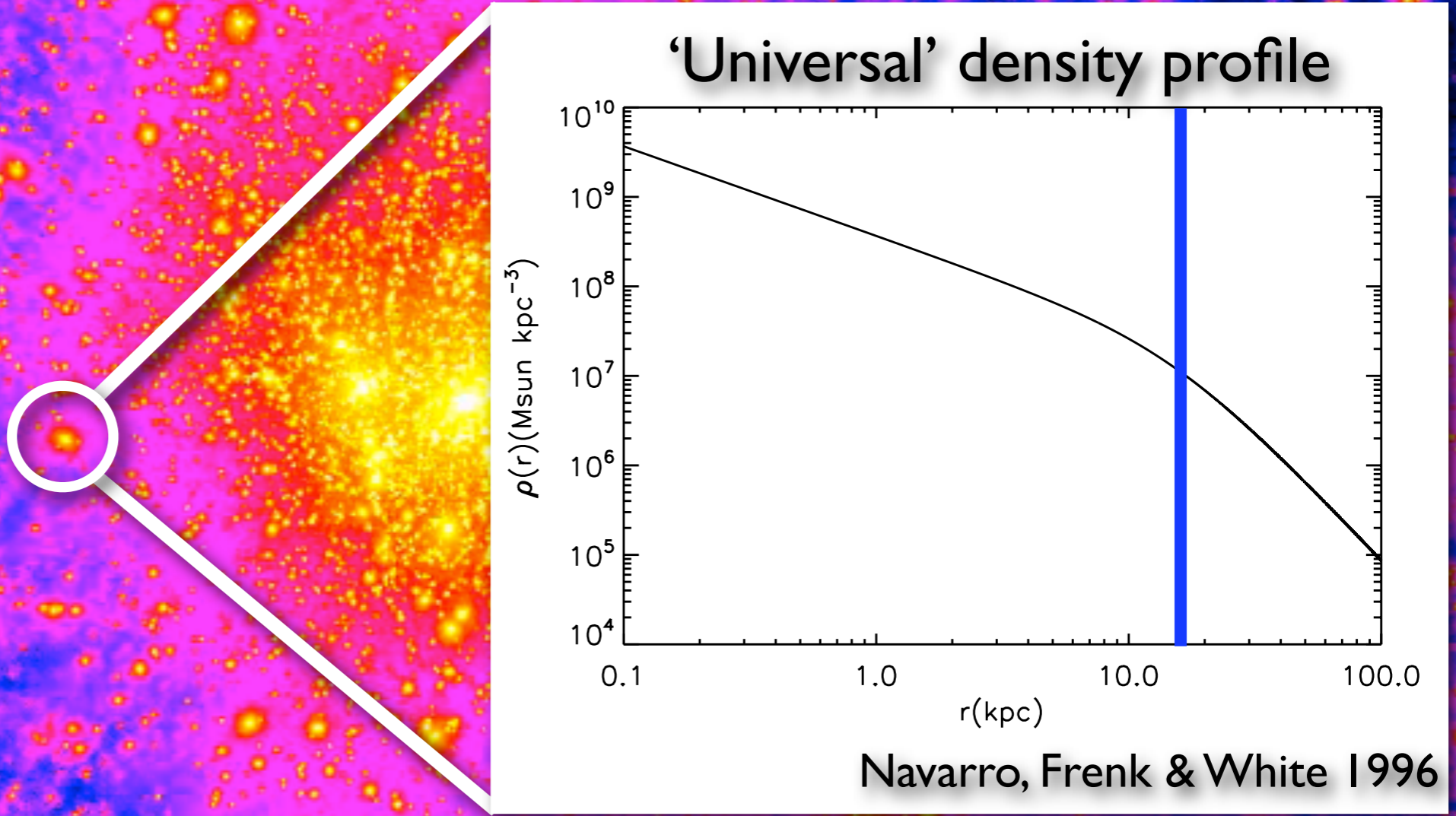


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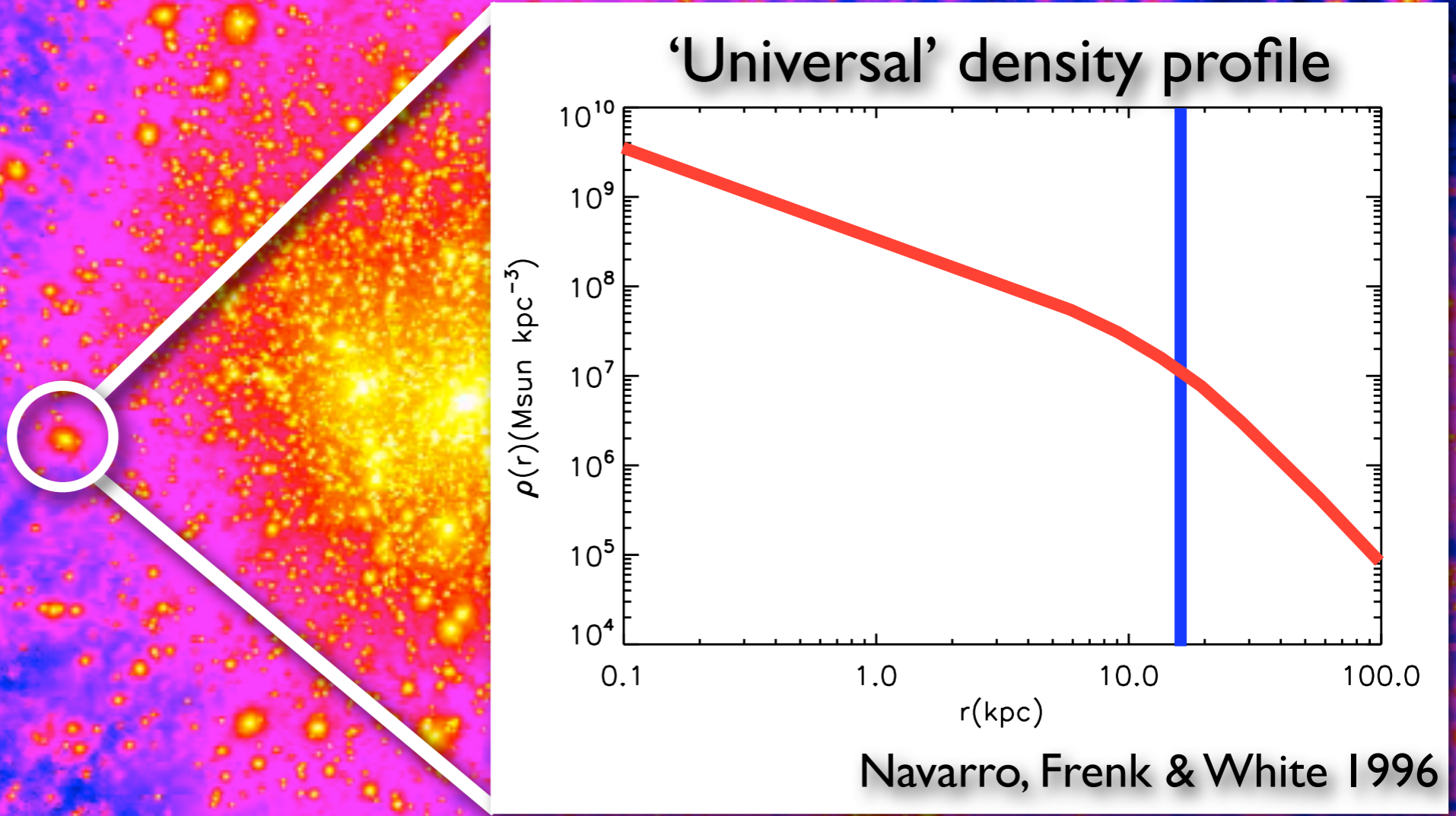


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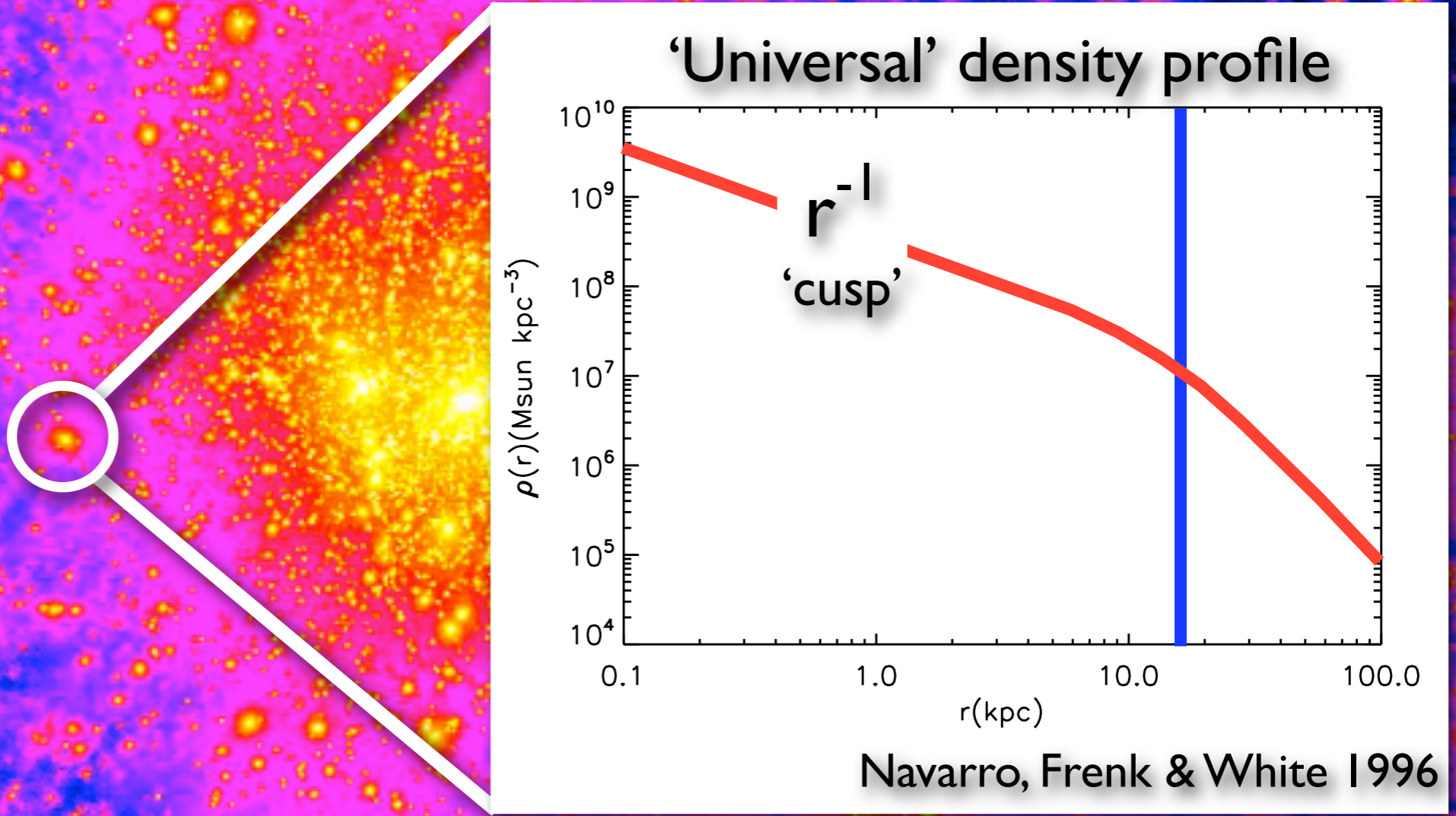


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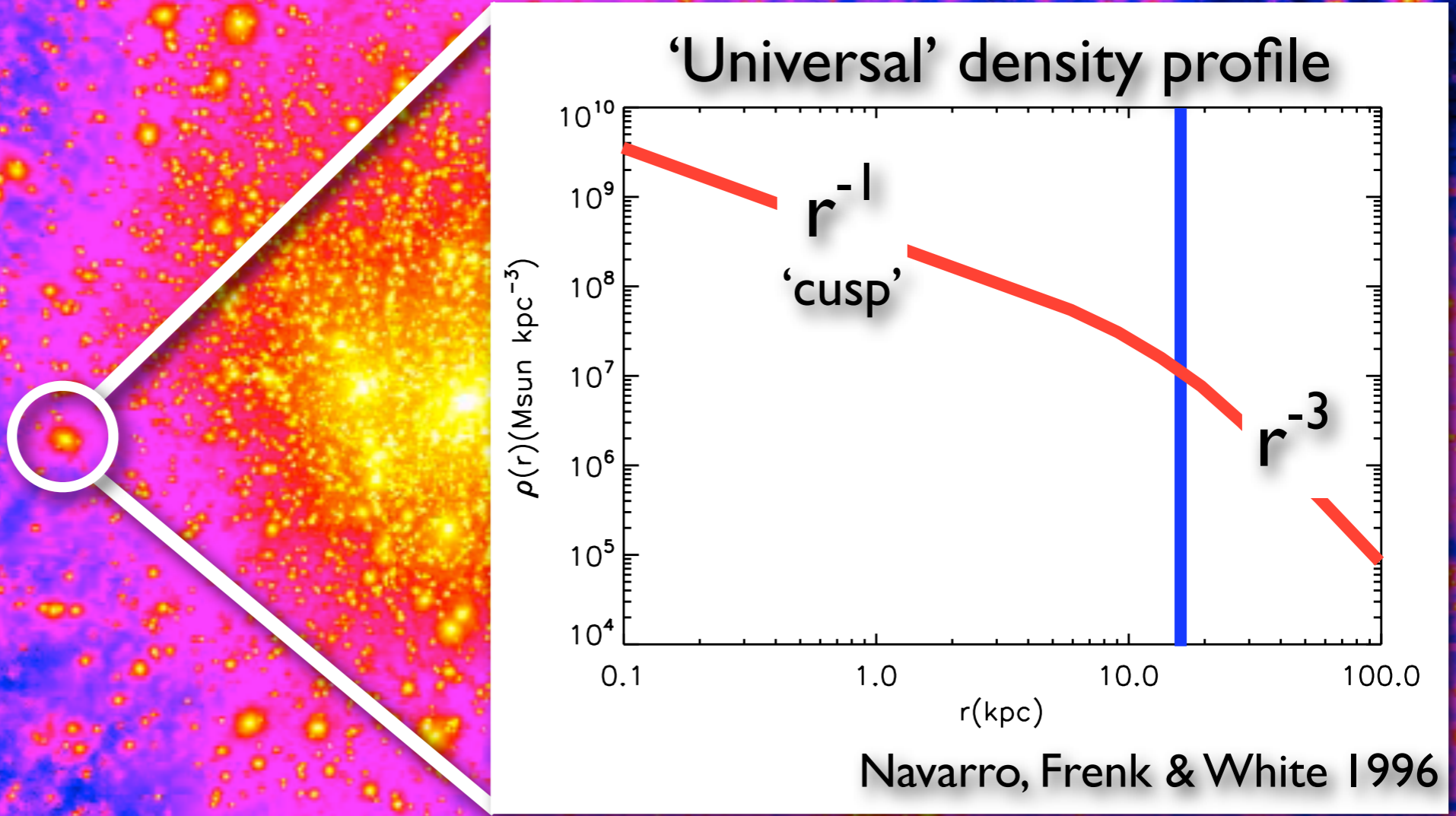
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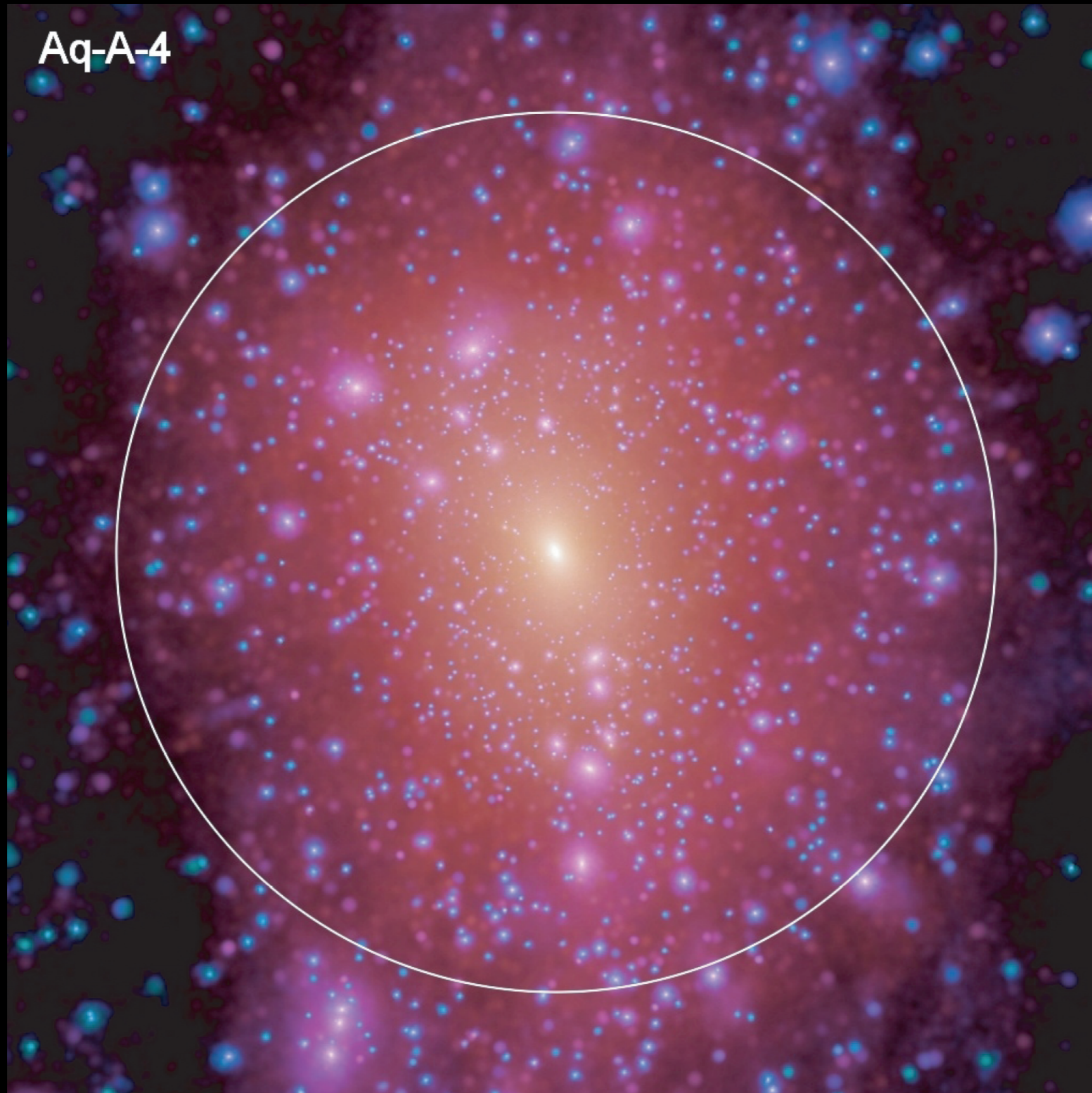
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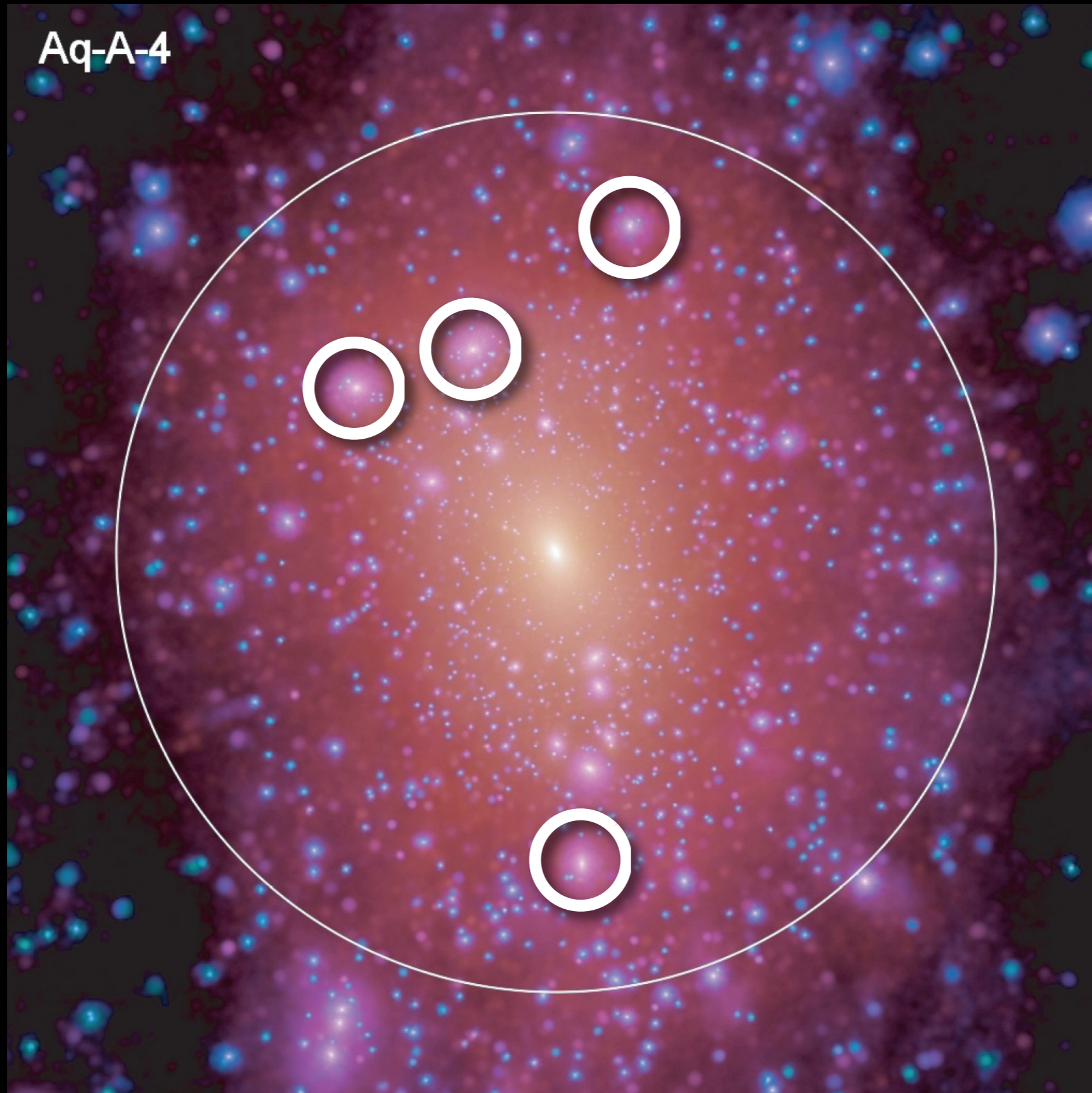
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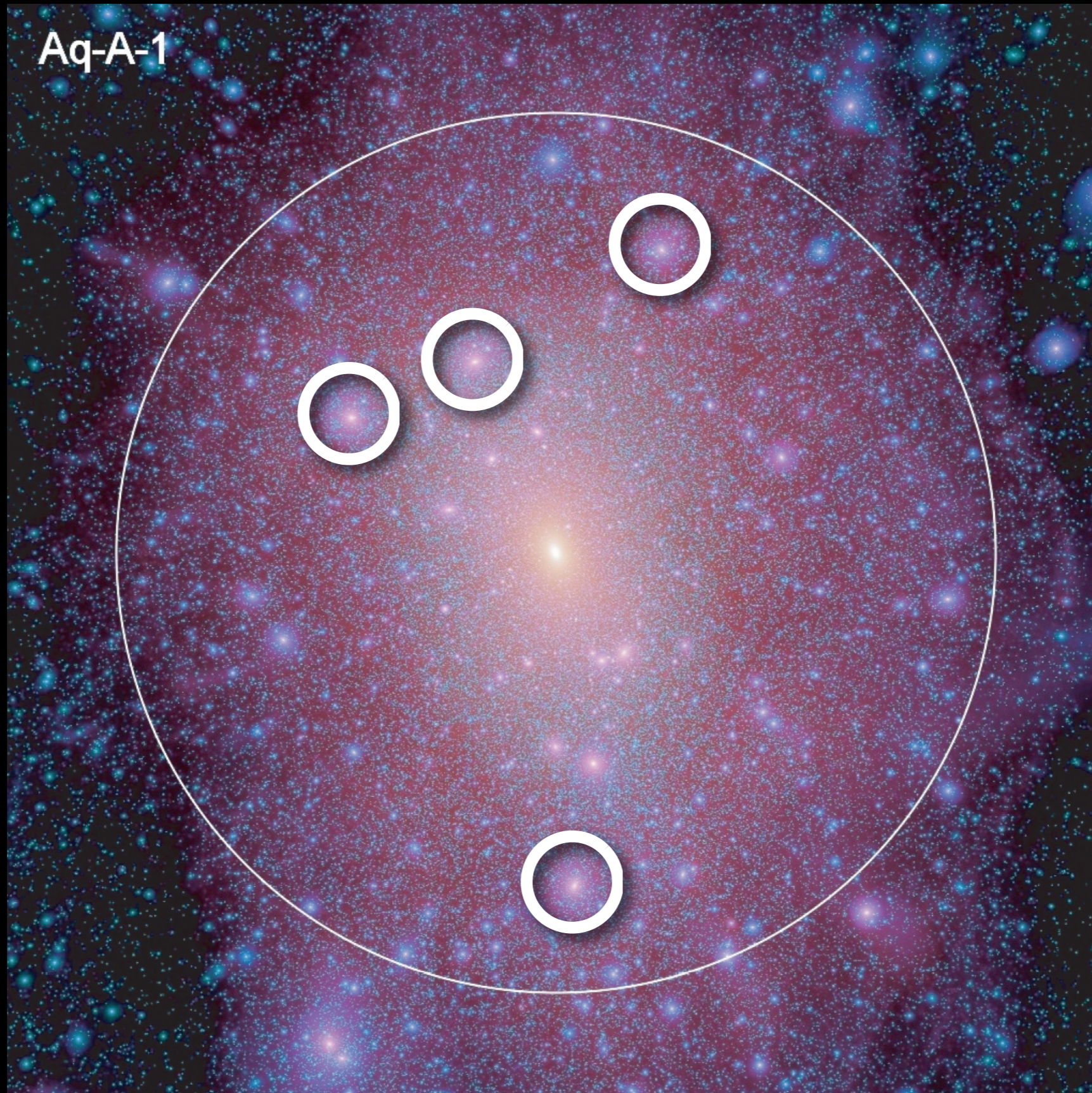
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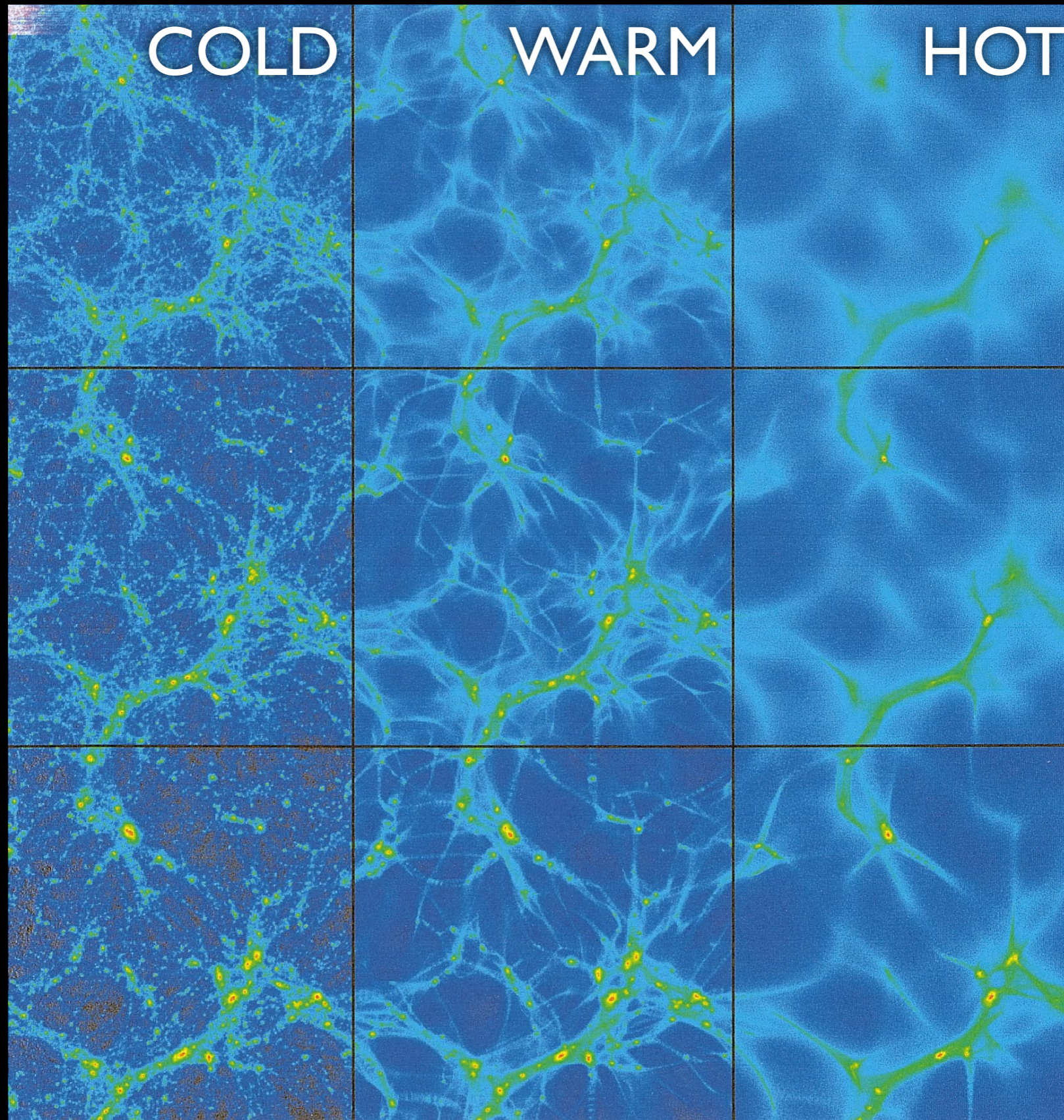
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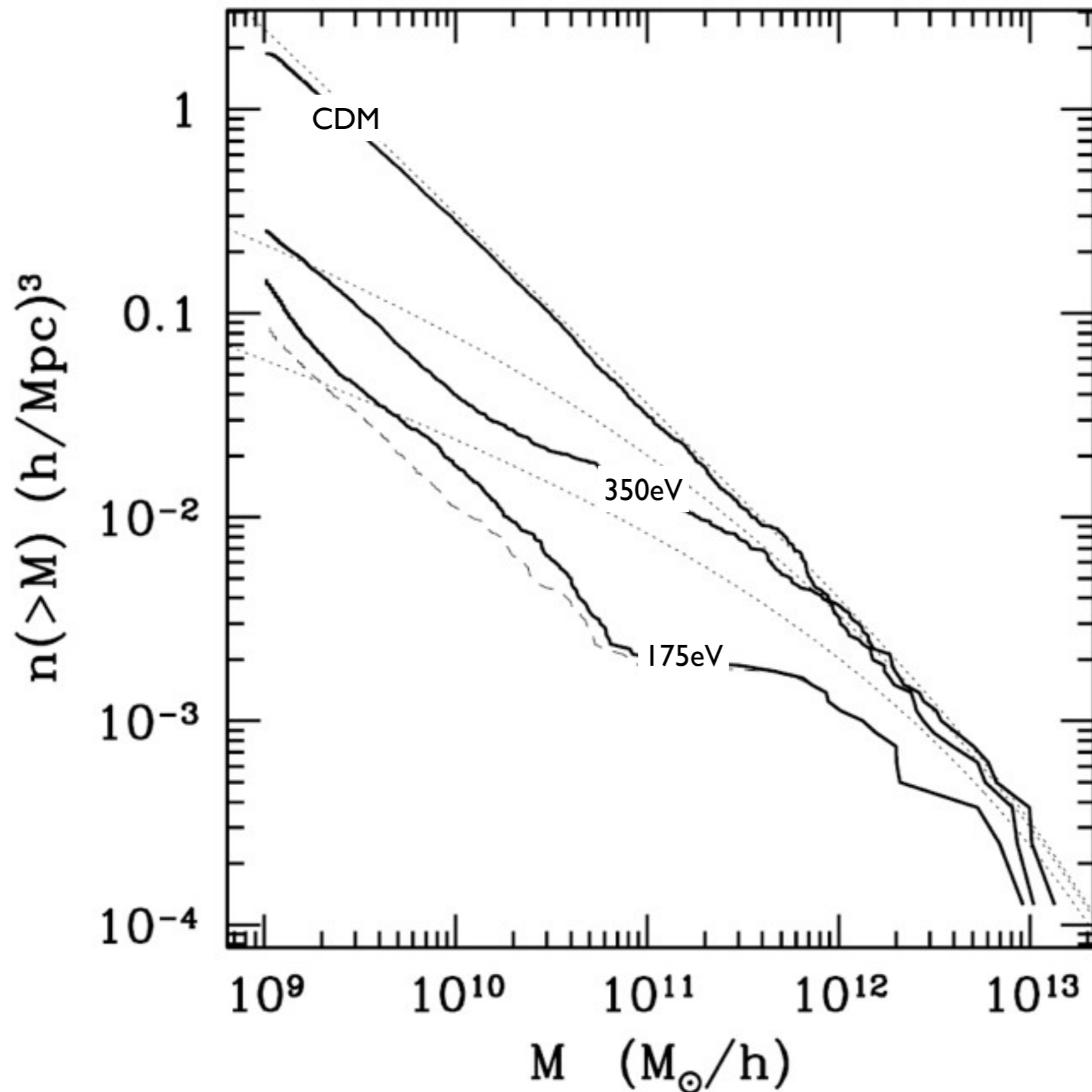


2. The trouble with Warm Dark Matter



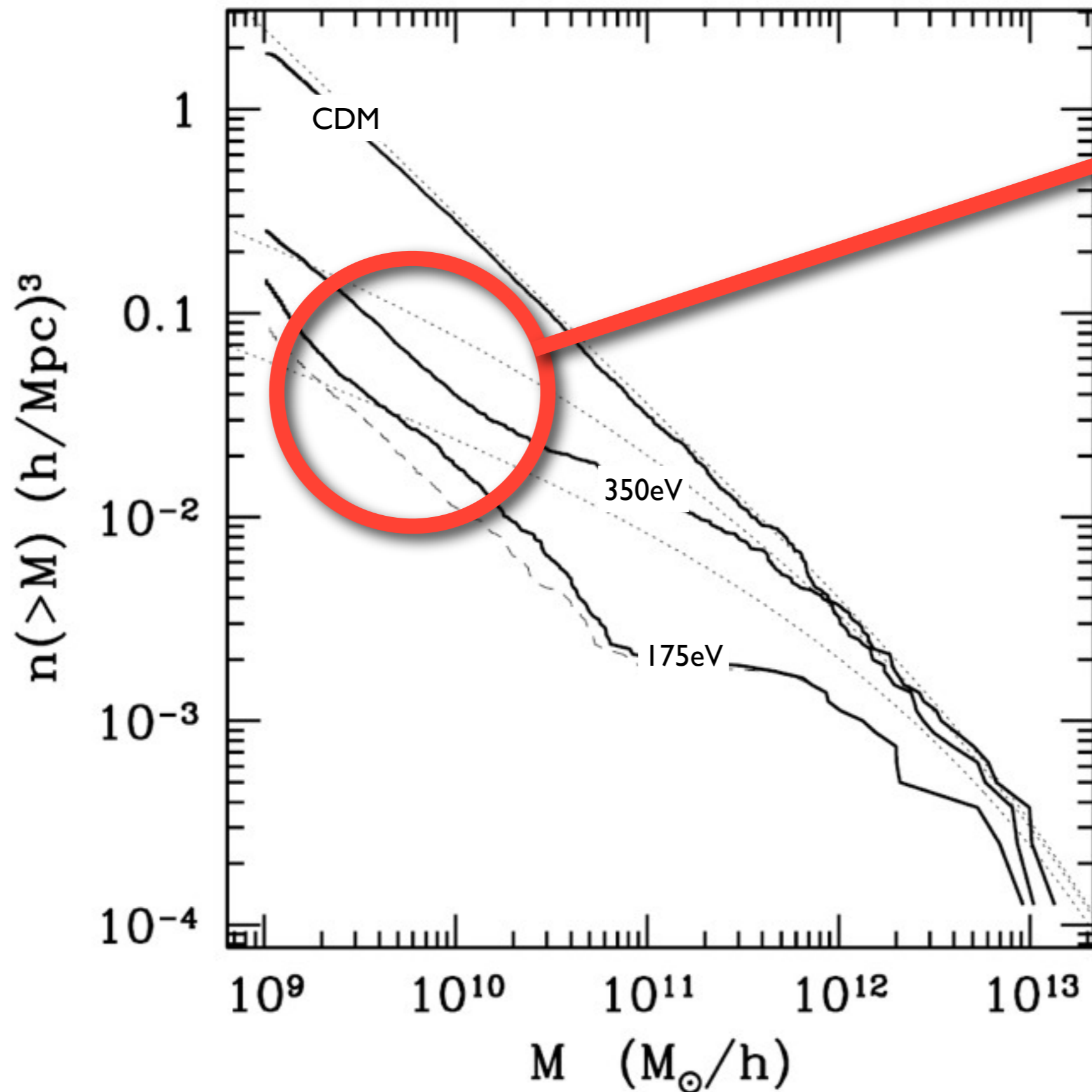
Bode et al. 2001

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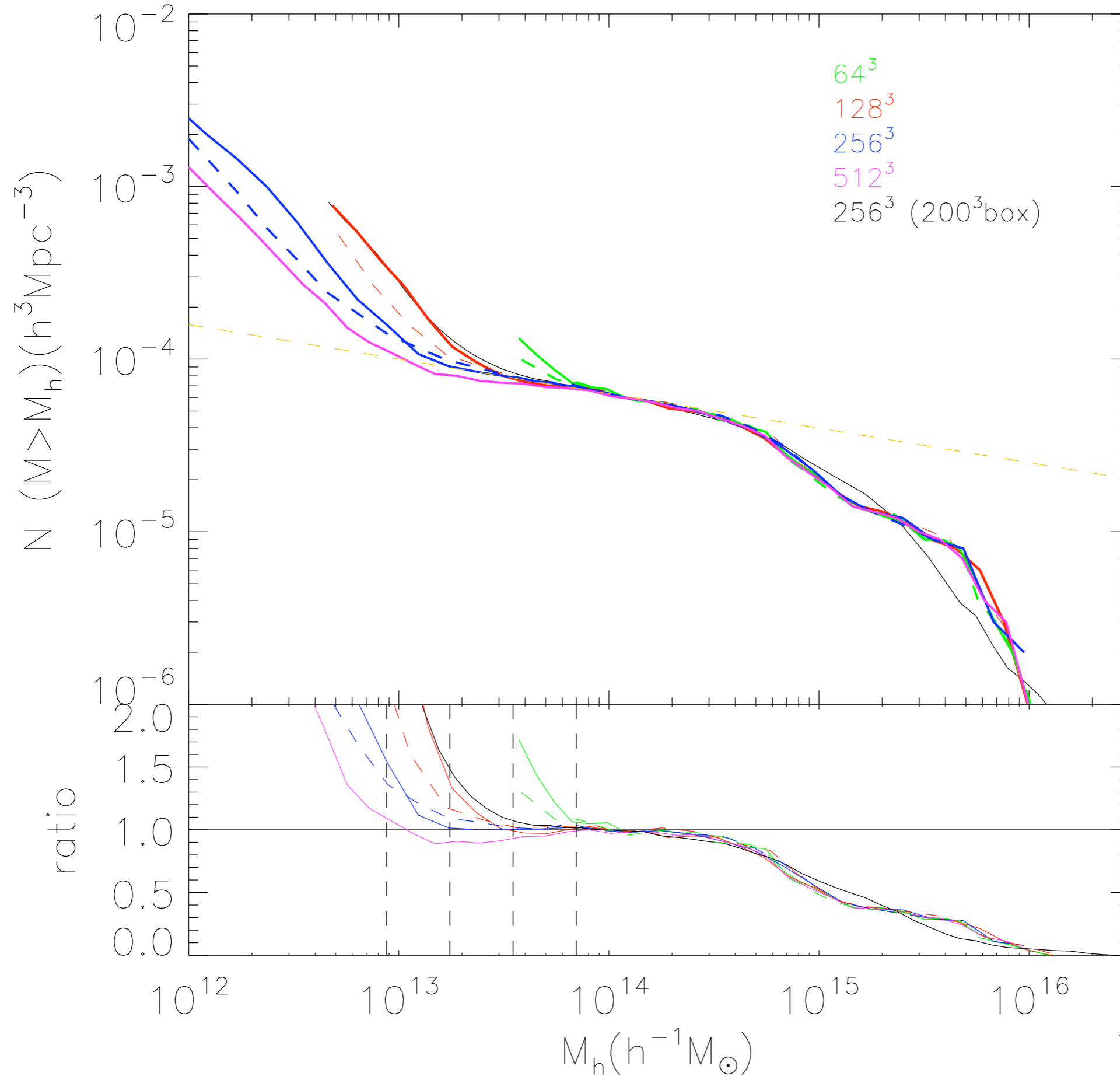


Fragmentation?

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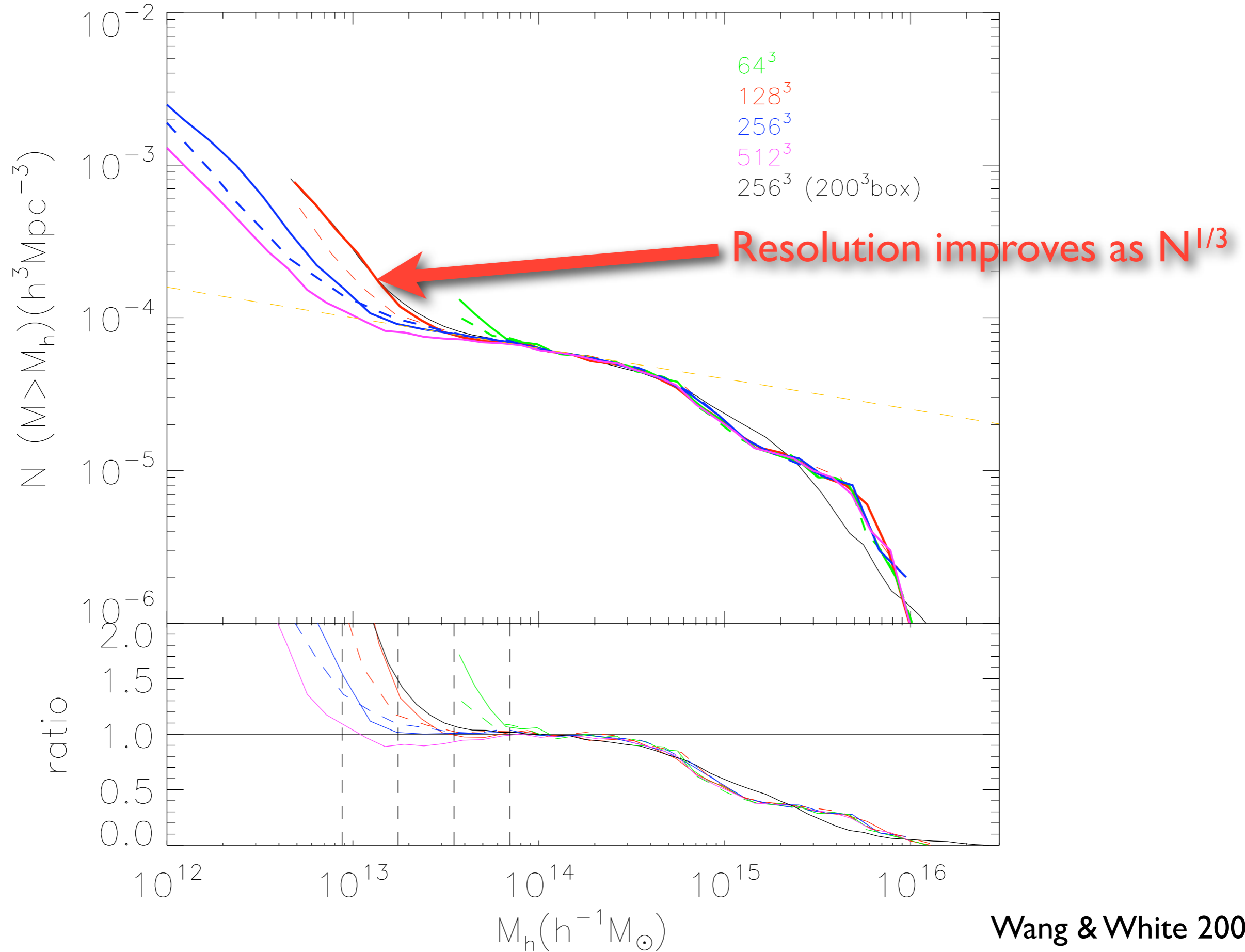
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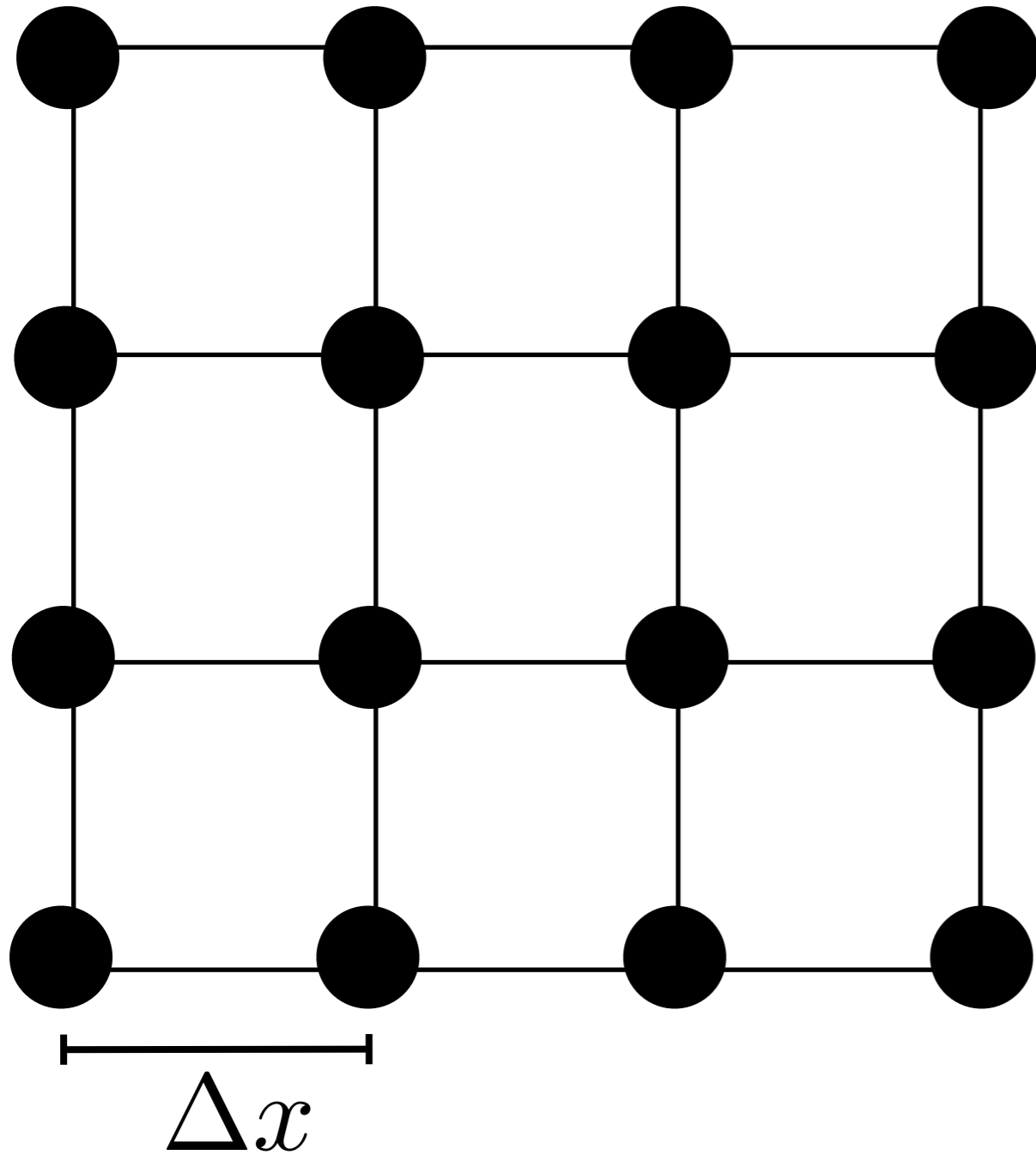
Wang & White 2007

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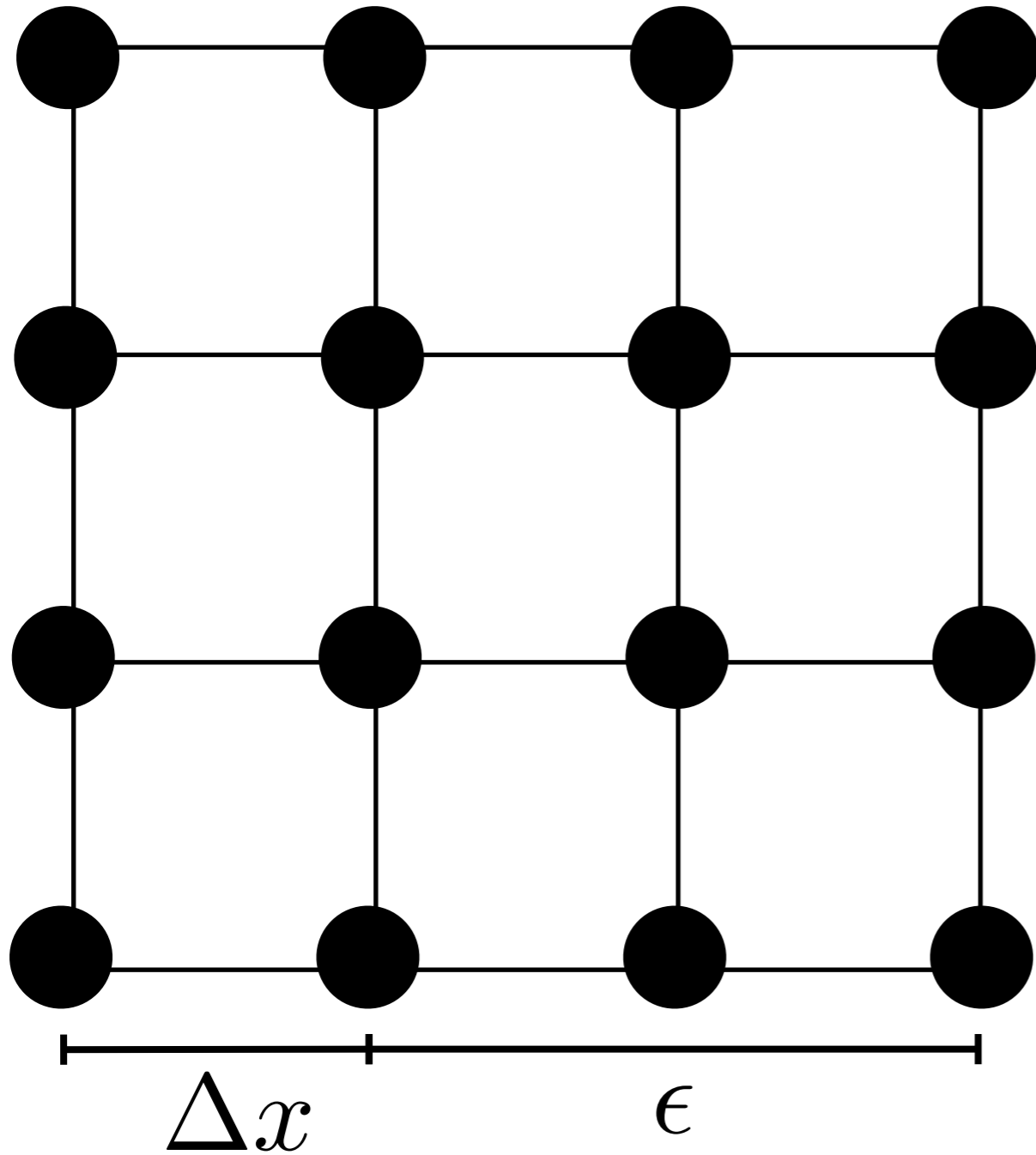


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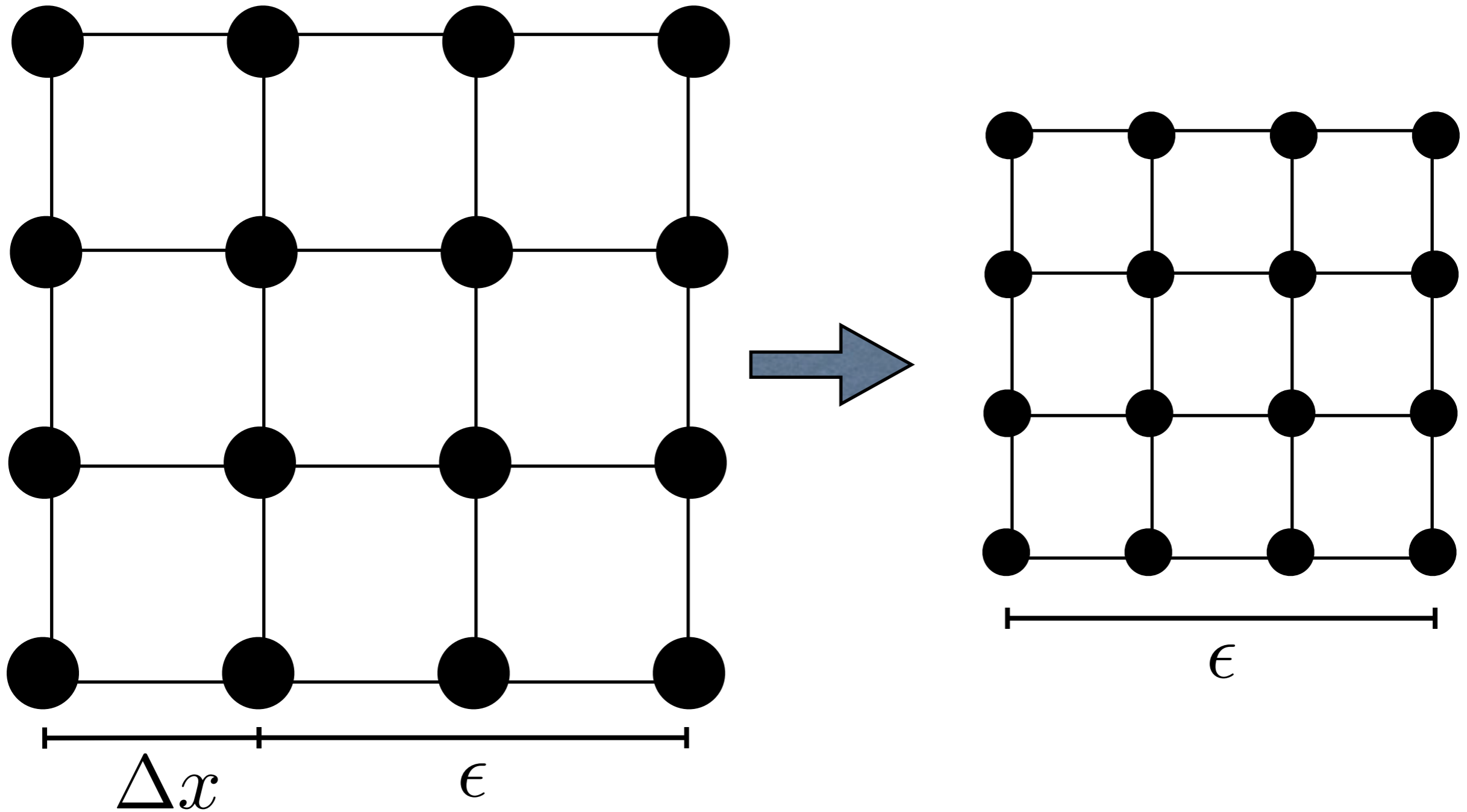
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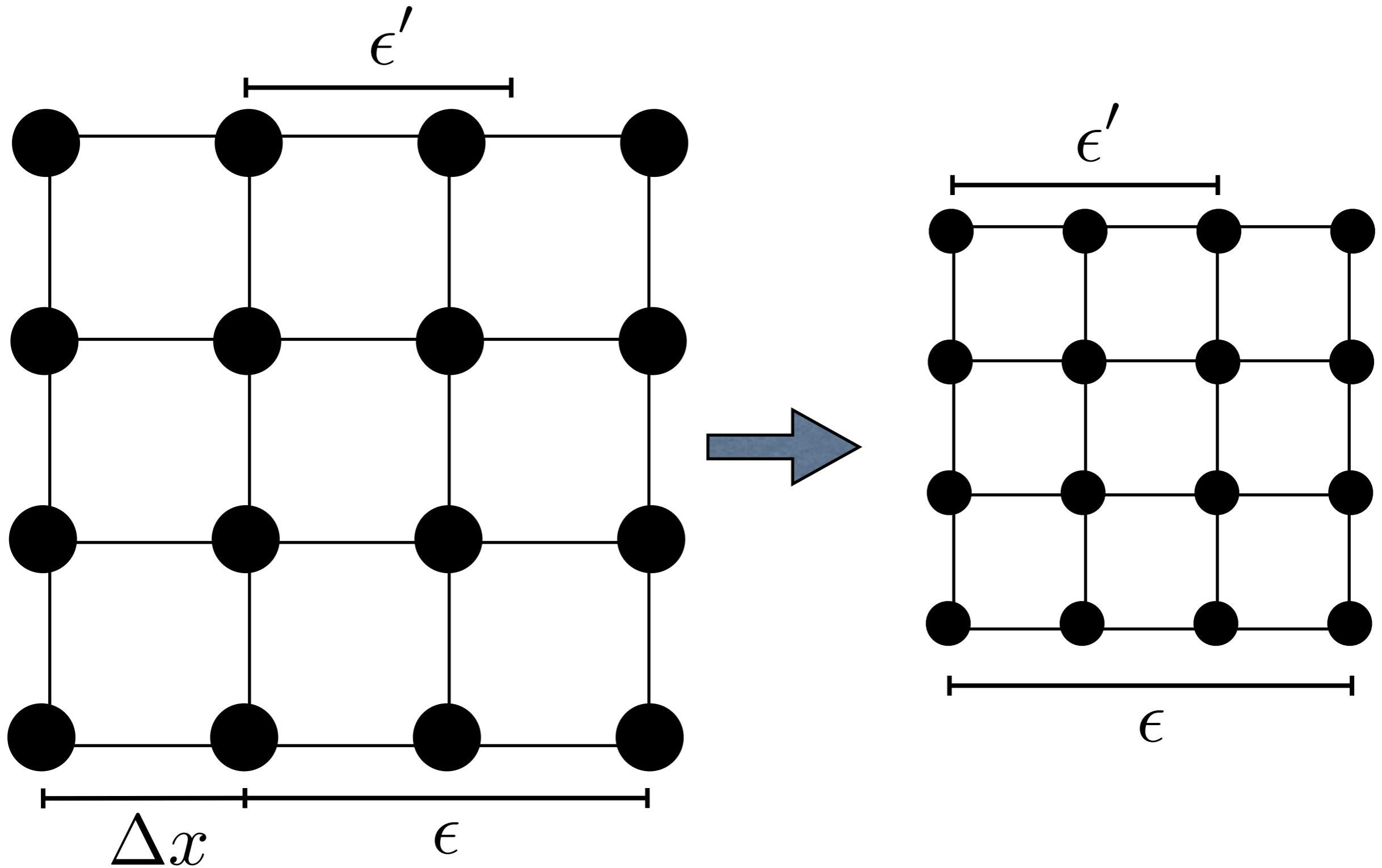
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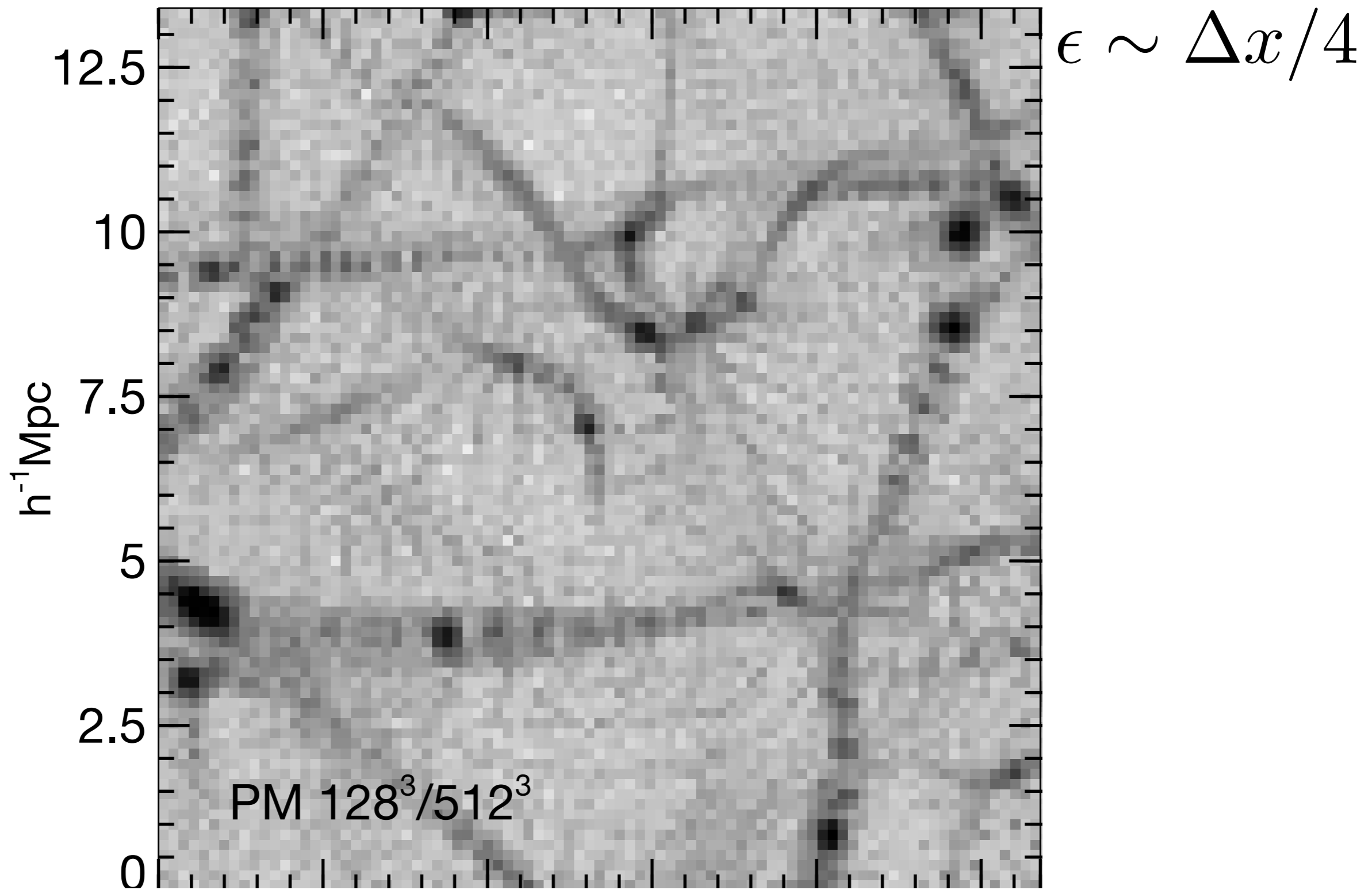
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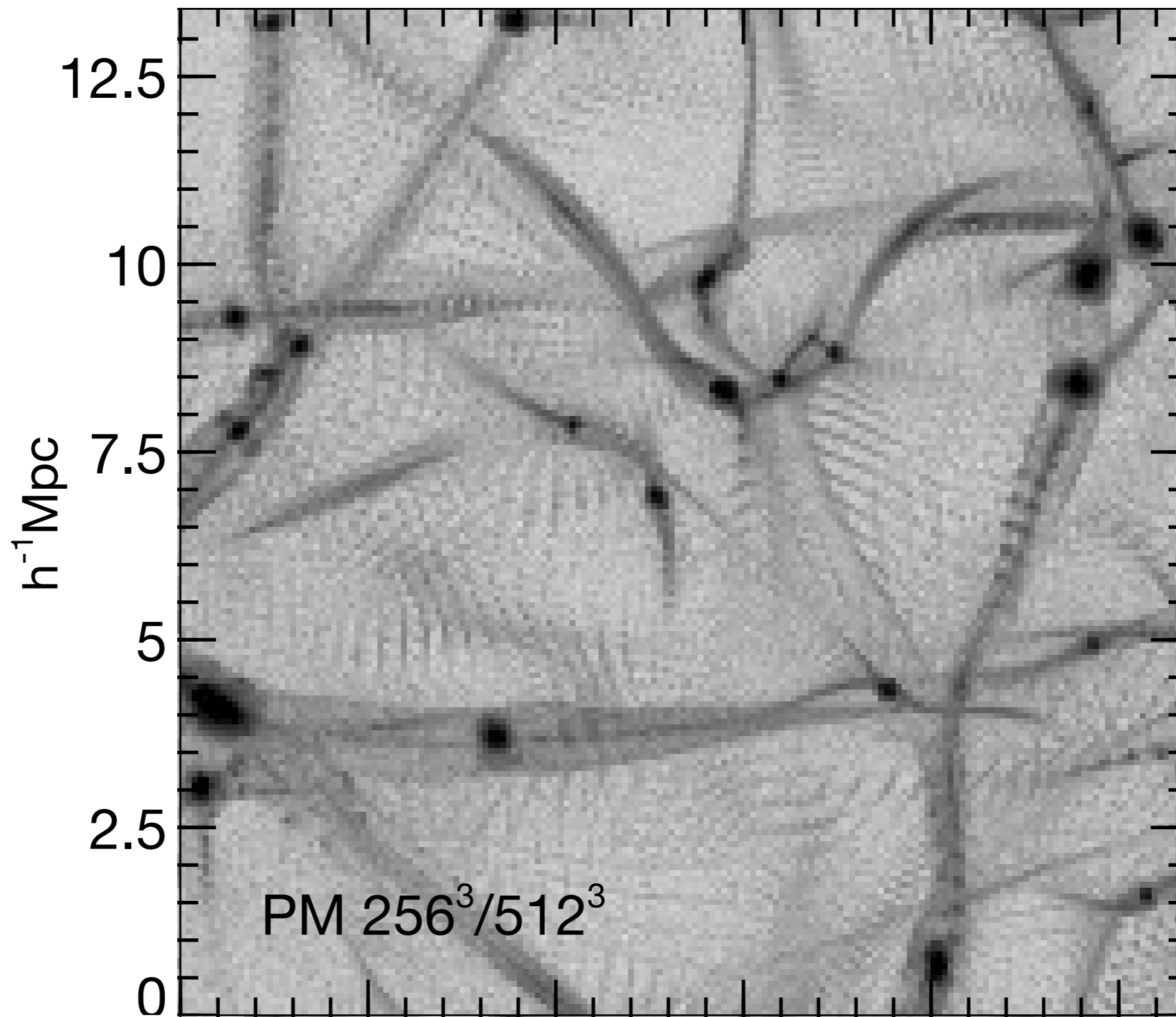


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Hahn et al. 2012; and see also Melott & Shandarin 1989; Splinter et al. 1998; Romeo et al. 2008

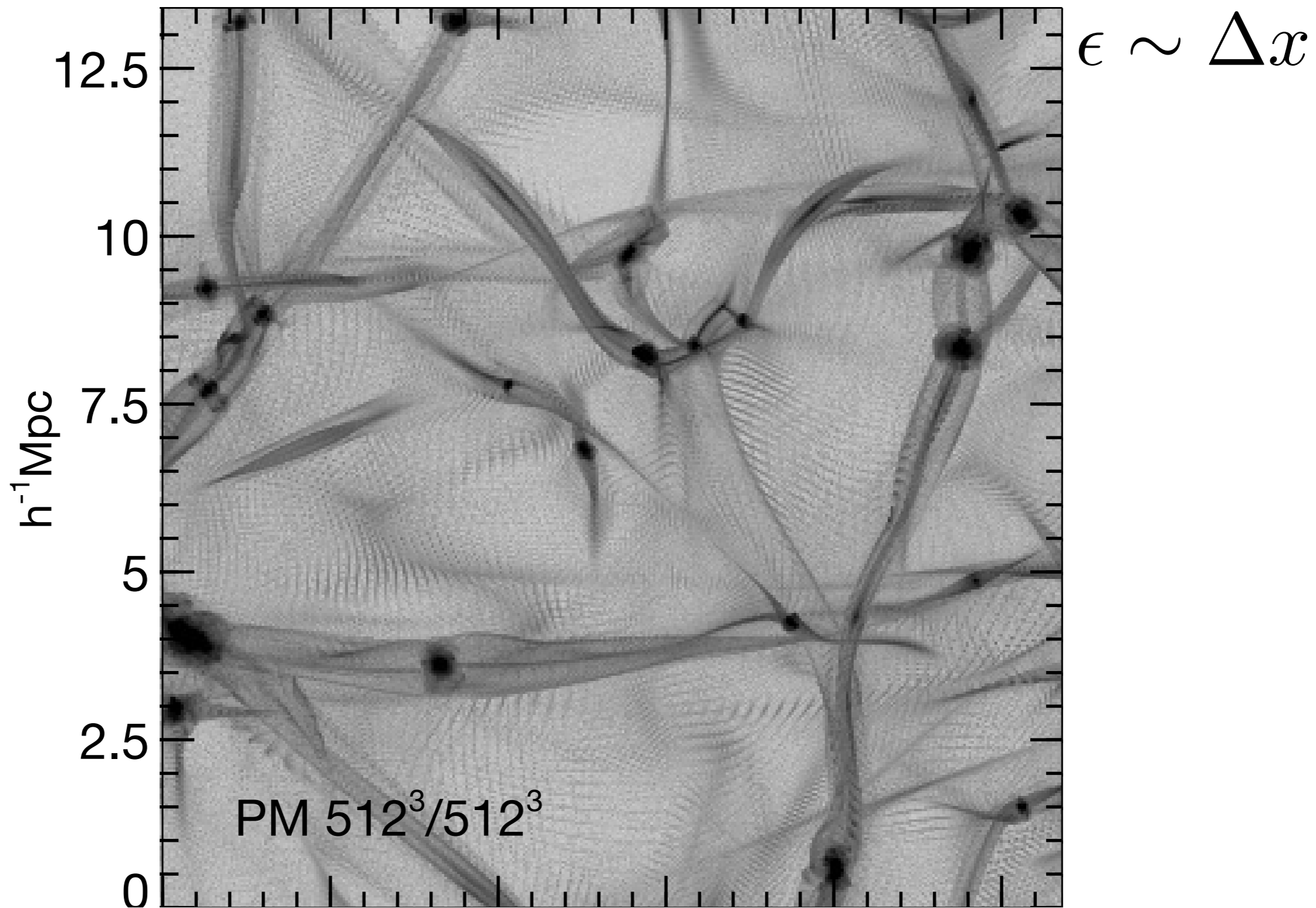
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$$\epsilon \sim \Delta x / 2$$

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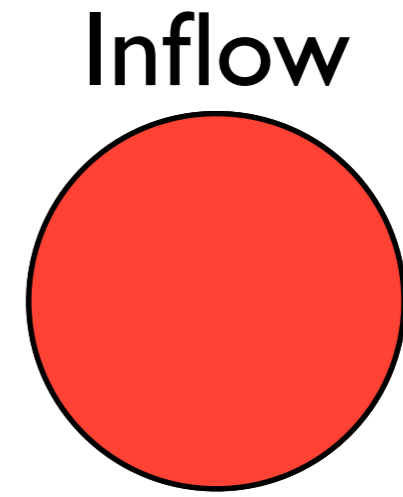
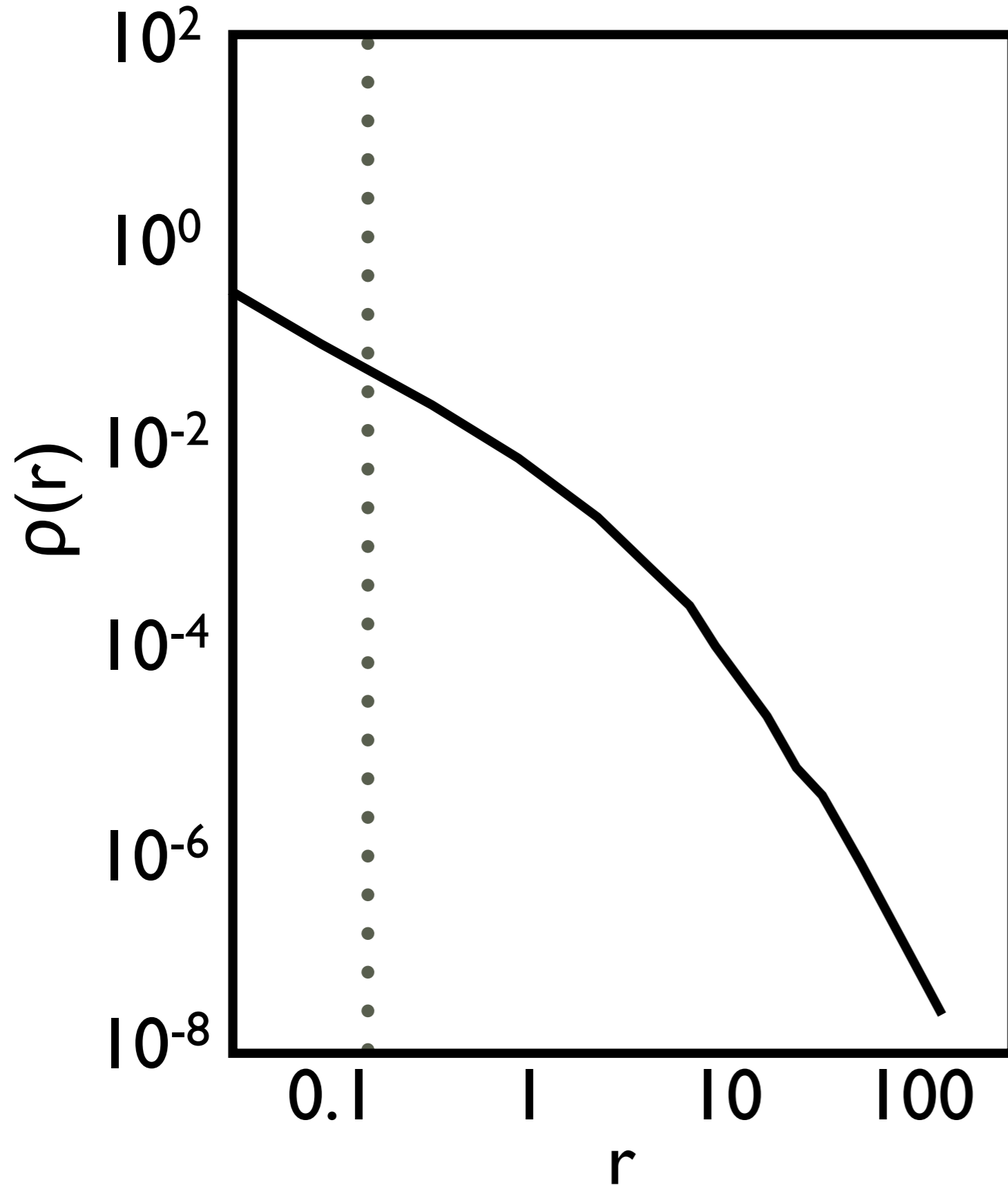
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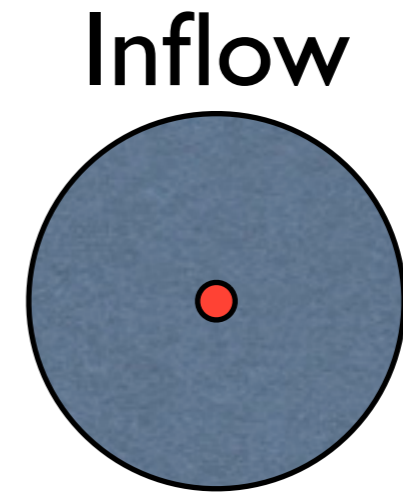
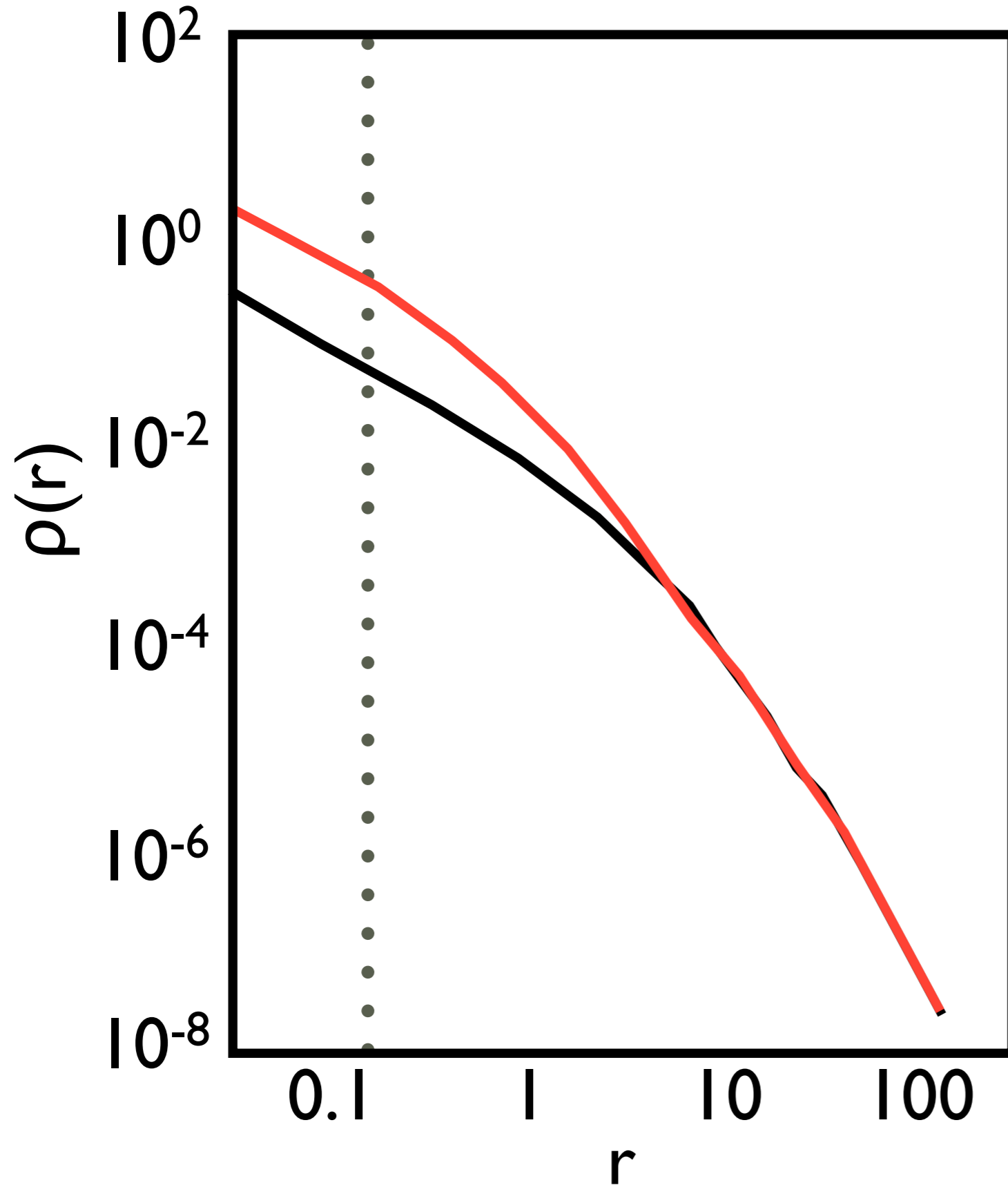
$$\epsilon = 2 \max[\Delta x]$$

3. The role of baryon physics | Cusp/core transformation



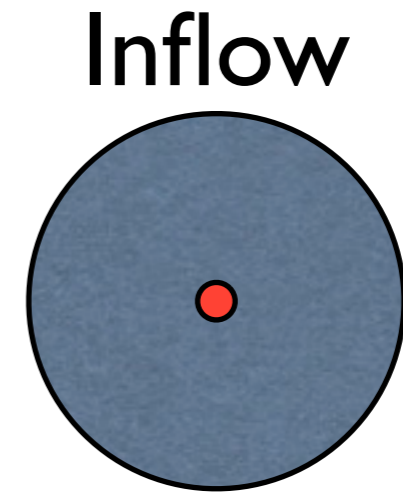
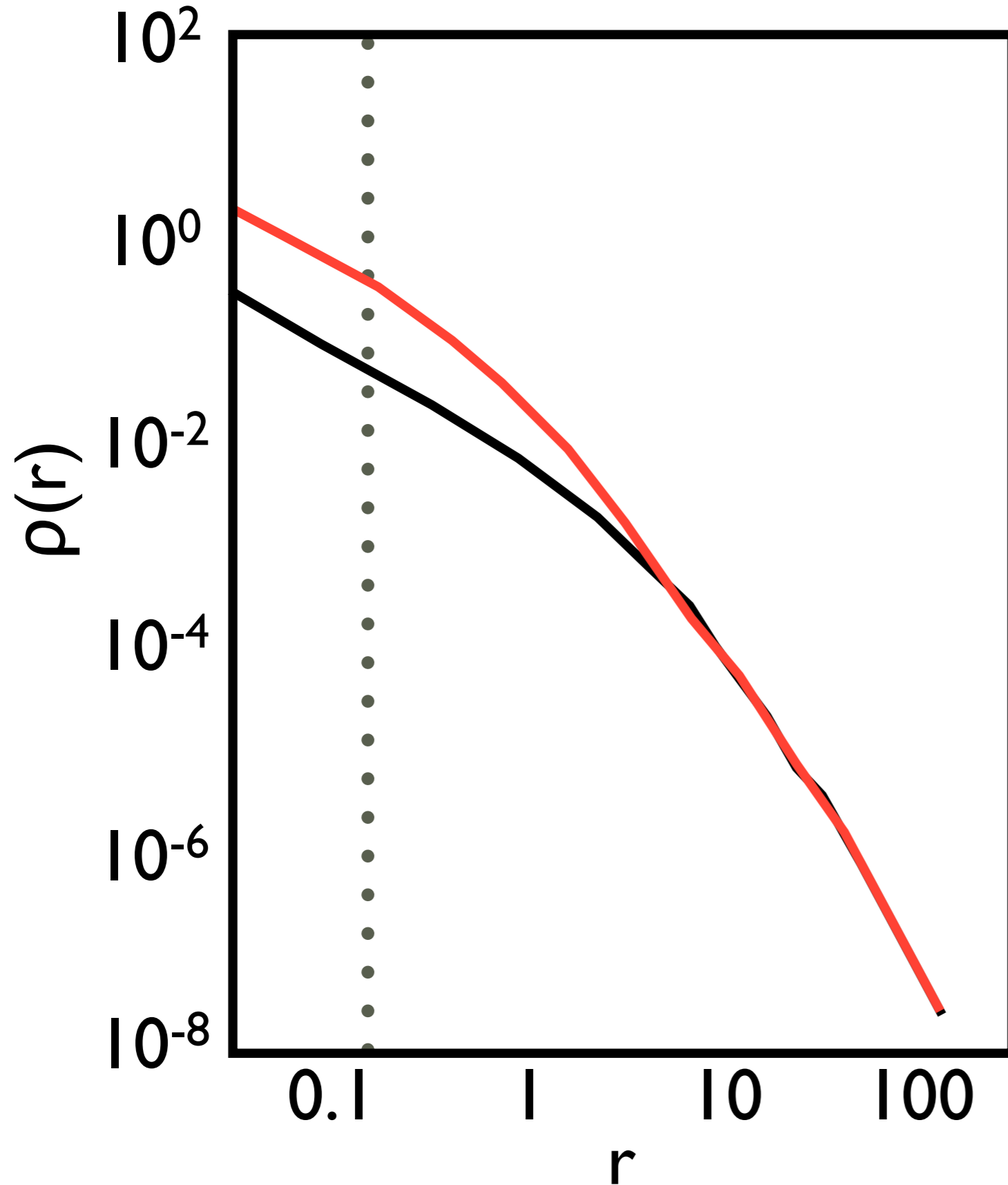
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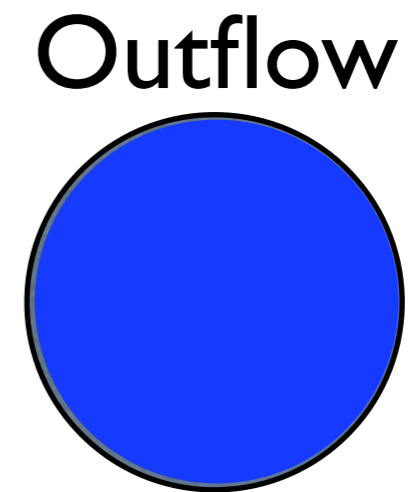
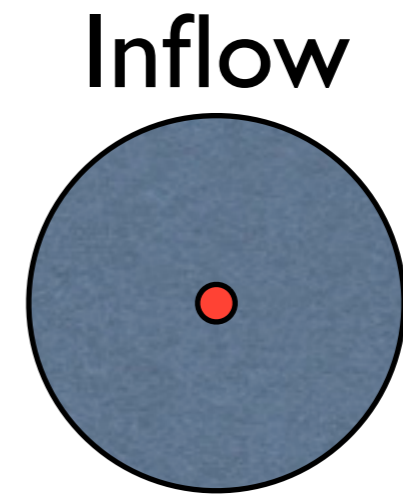
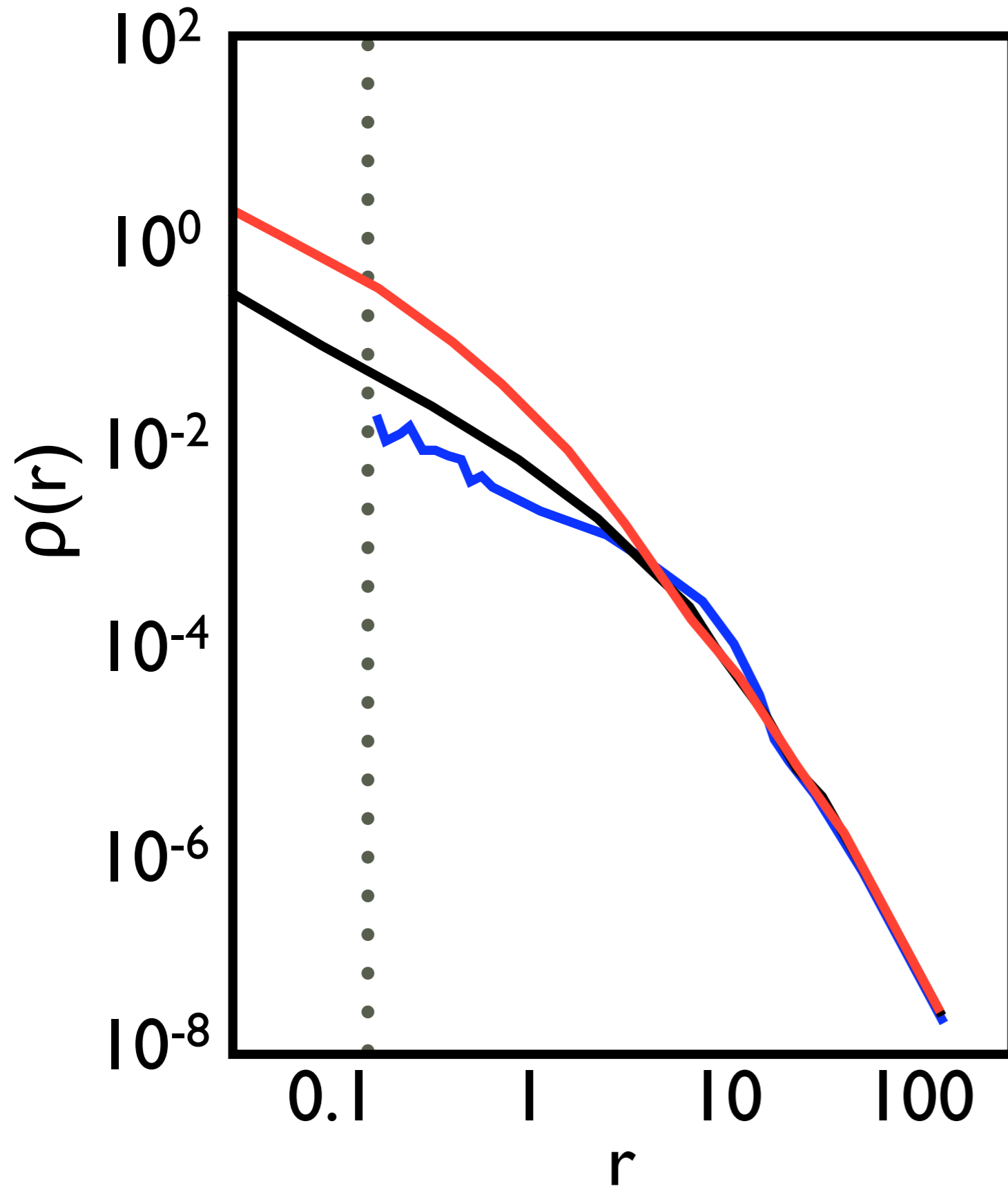
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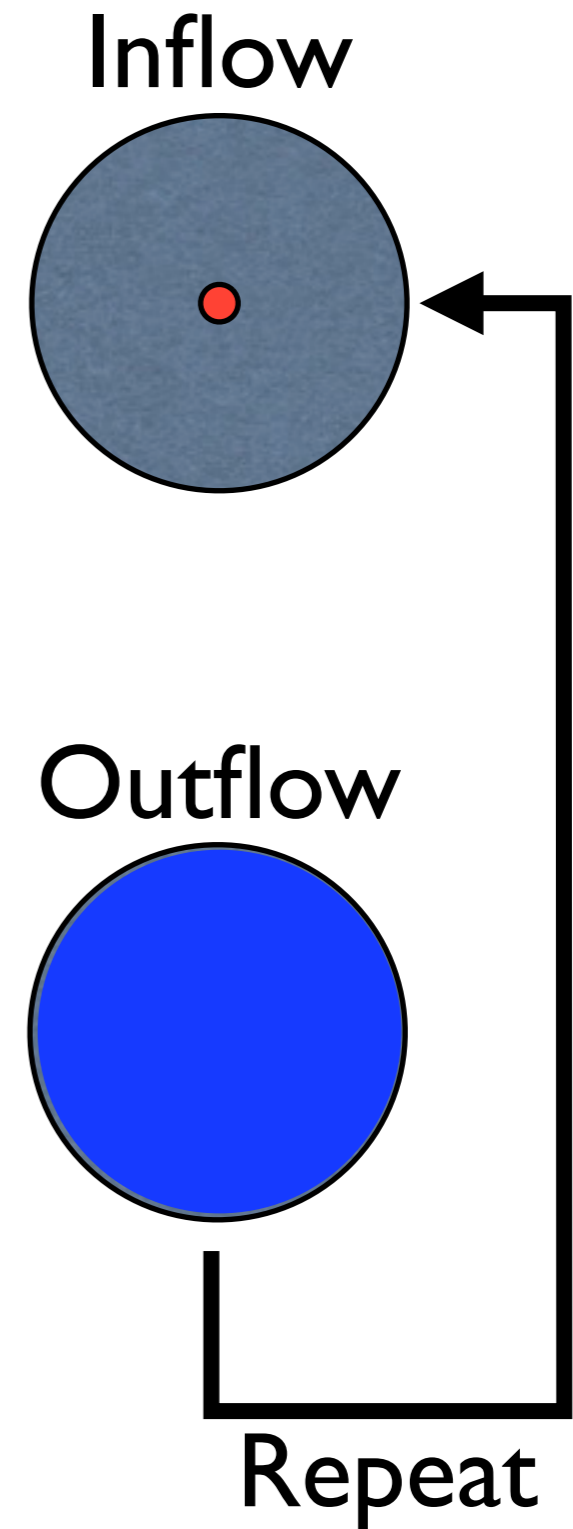
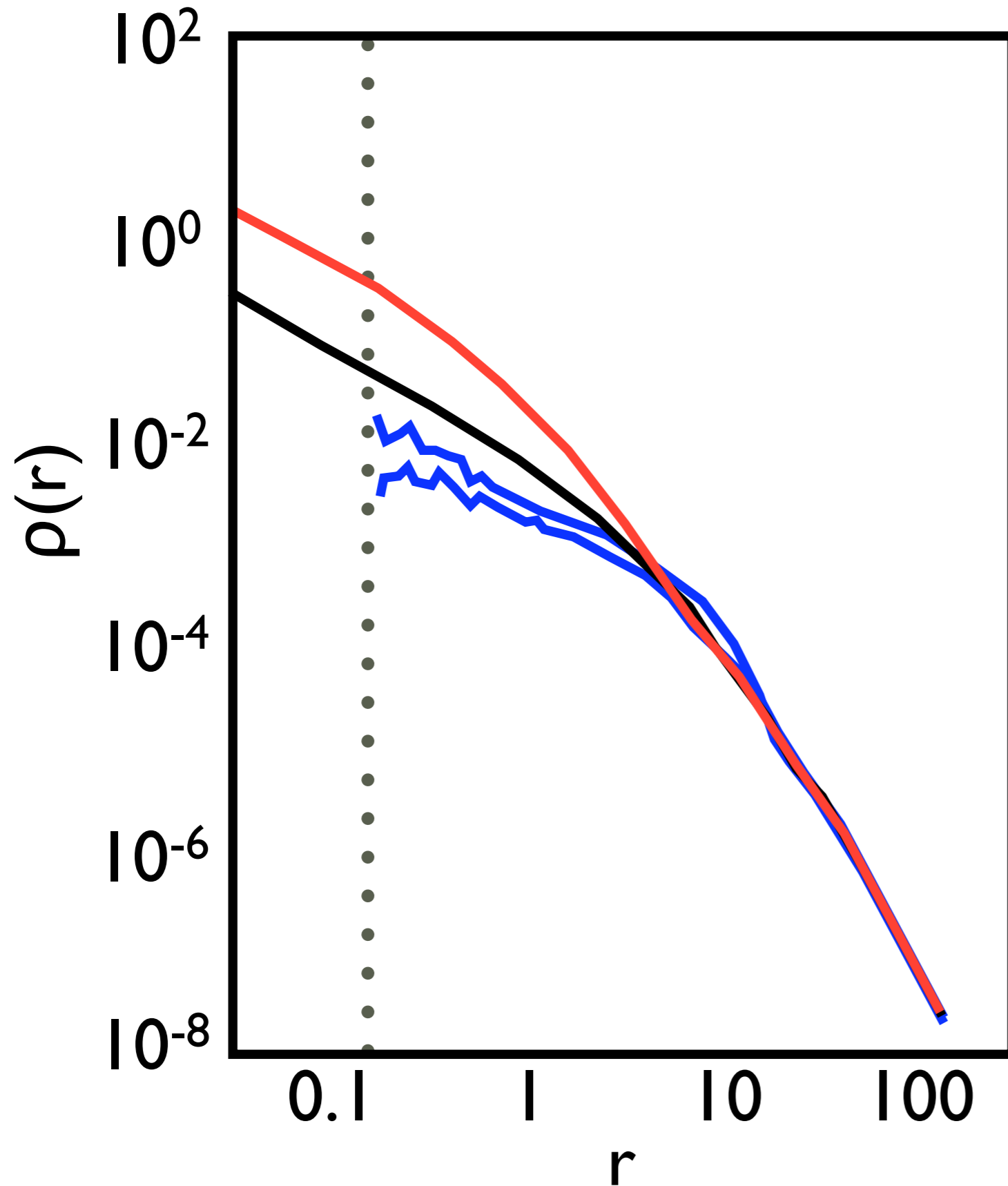
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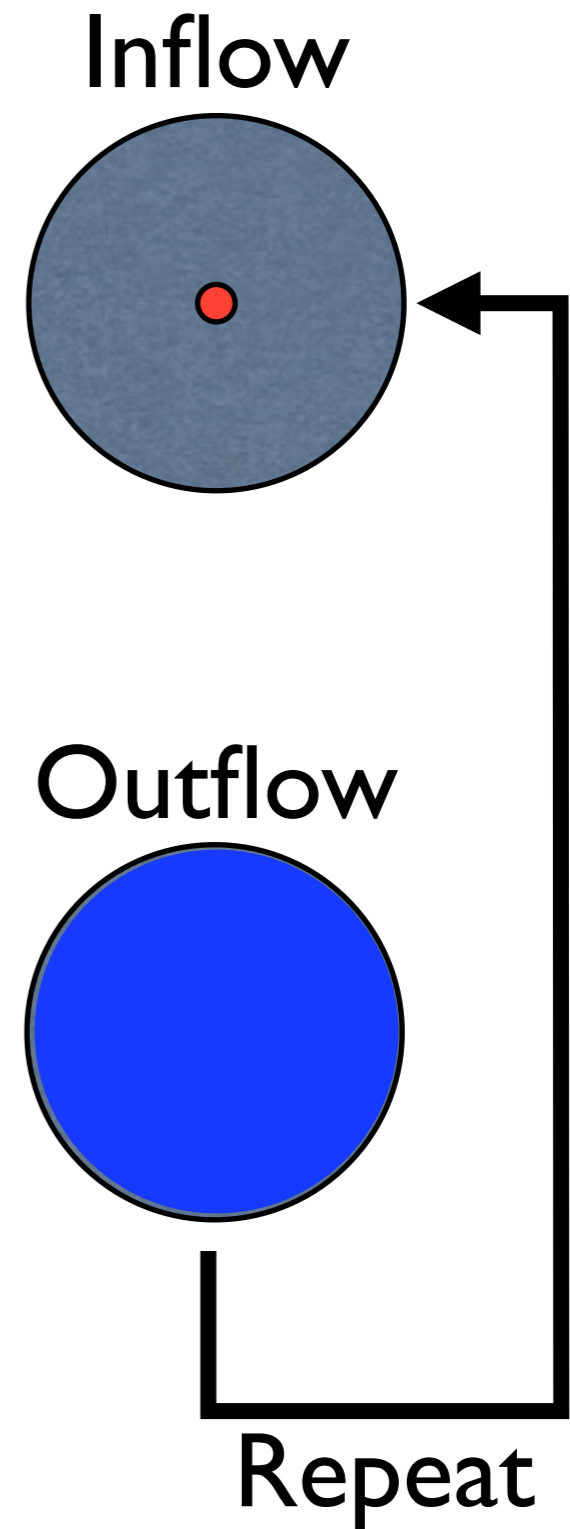
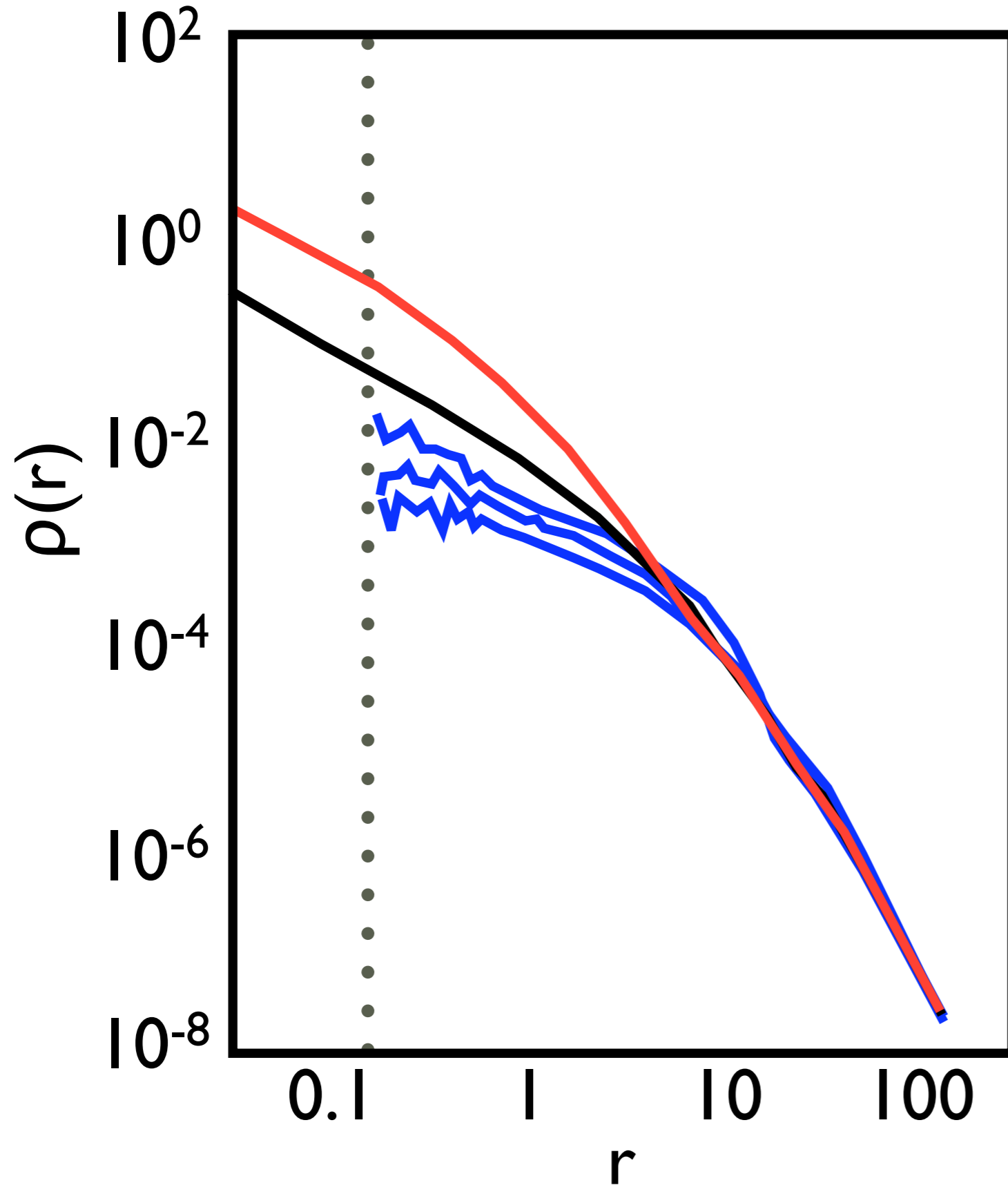
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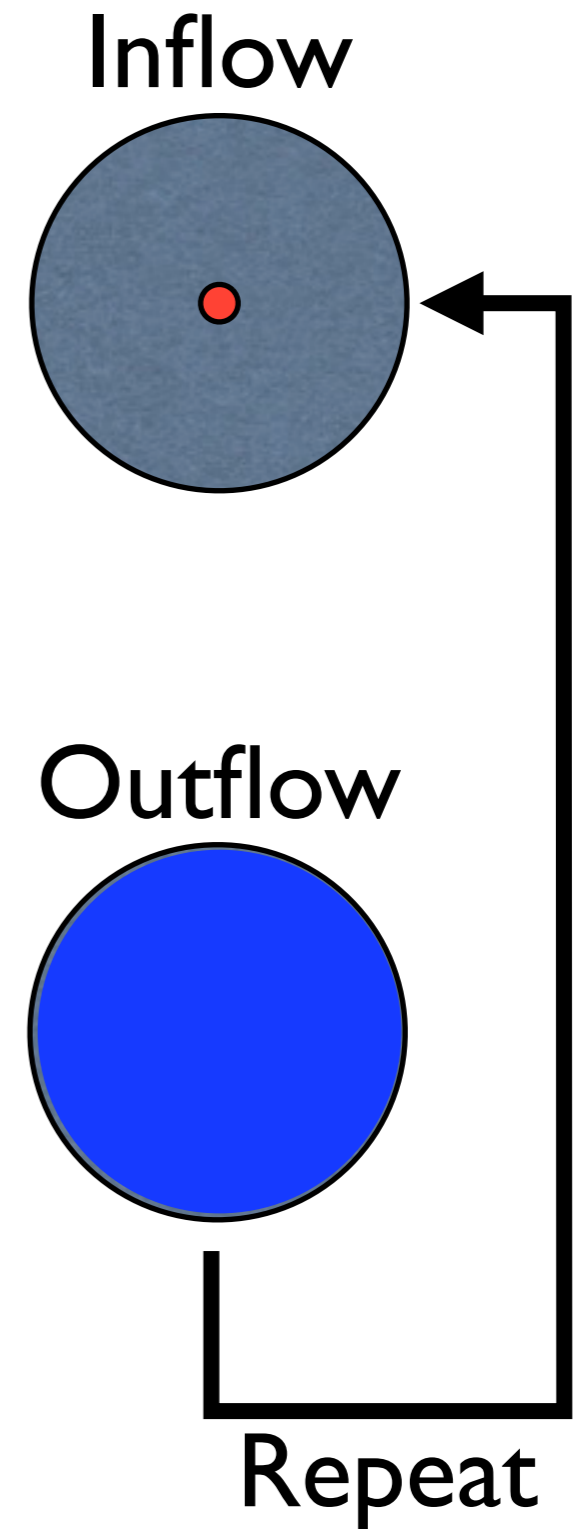
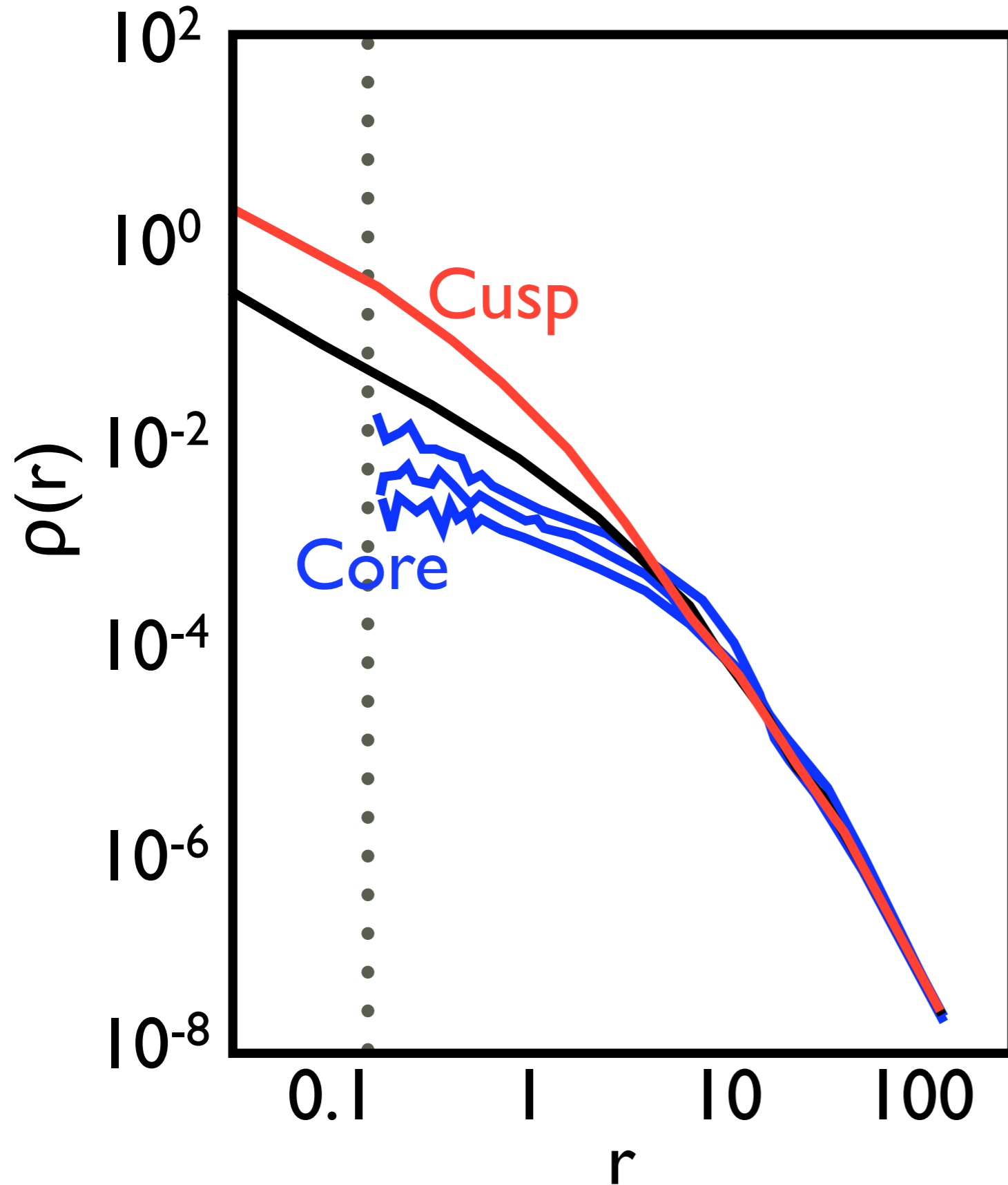
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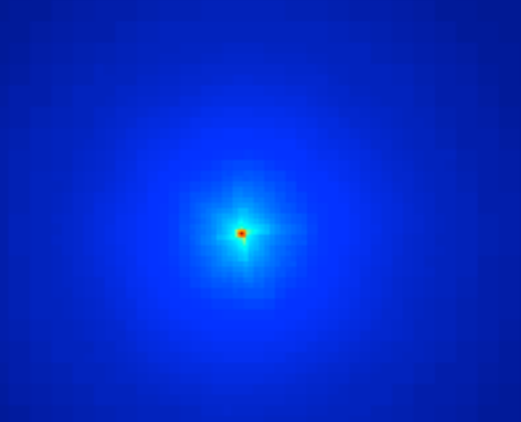
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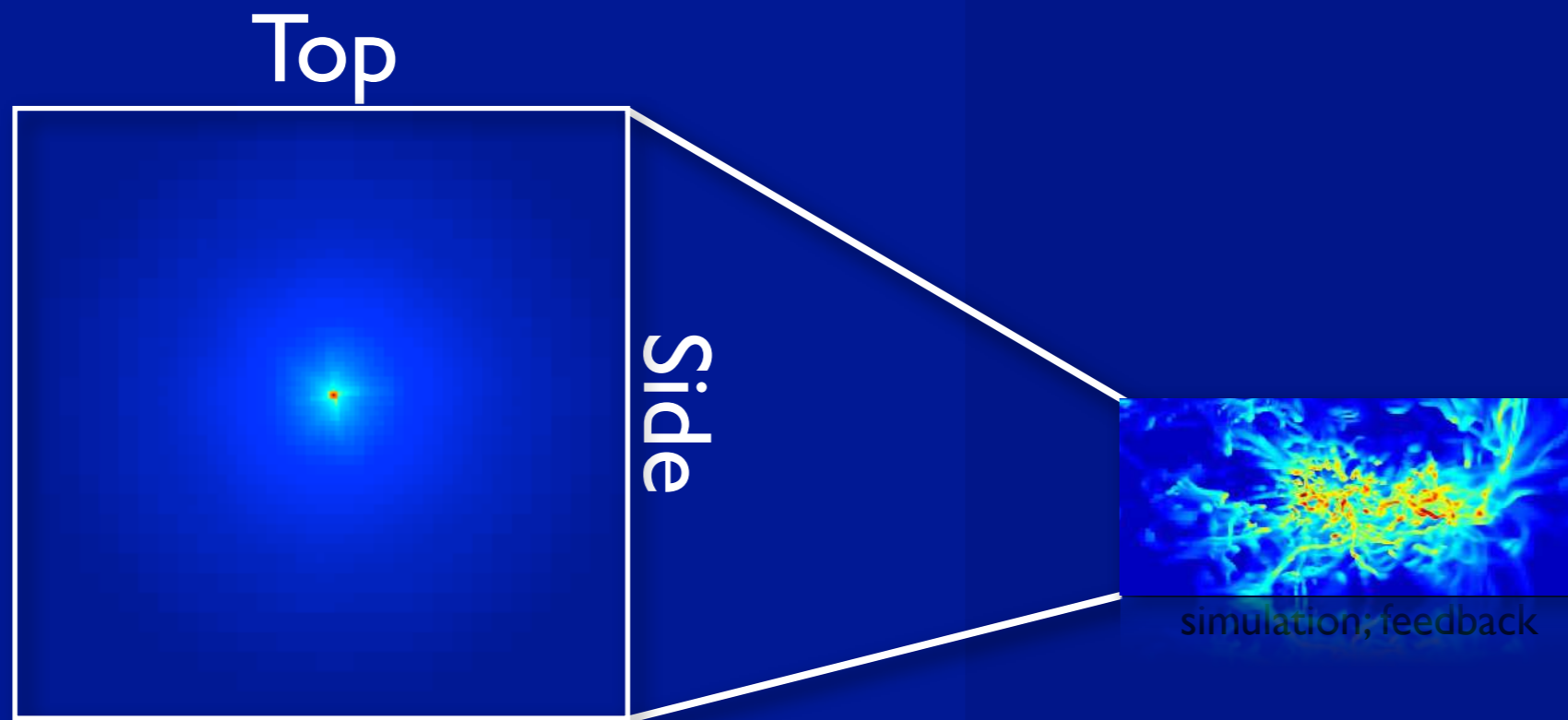
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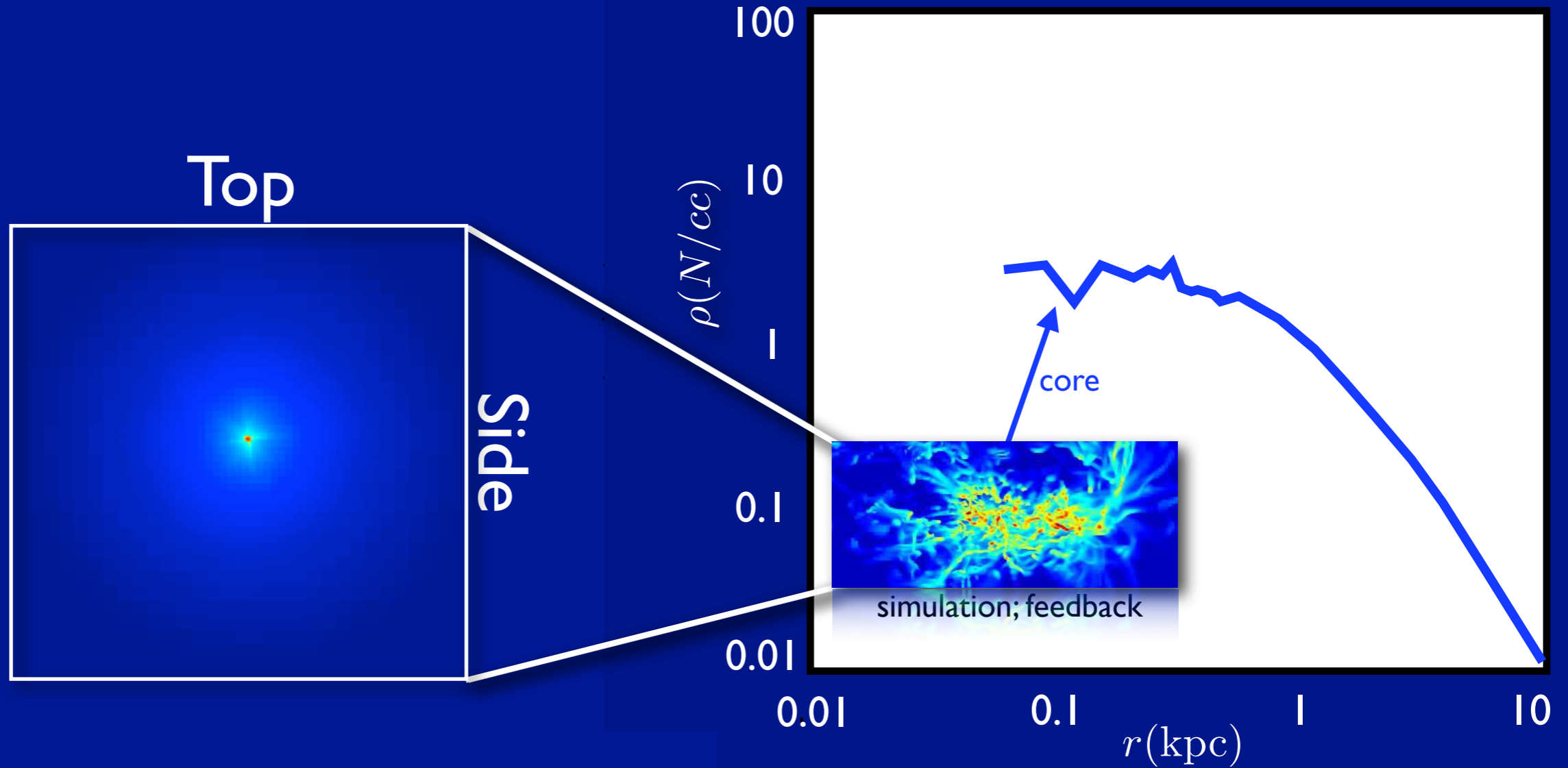
Teyssier, Pontzen, Dubois & Read, 2013; and see Pontzen & Governato 2012; Mashchenko et al. 2006/8

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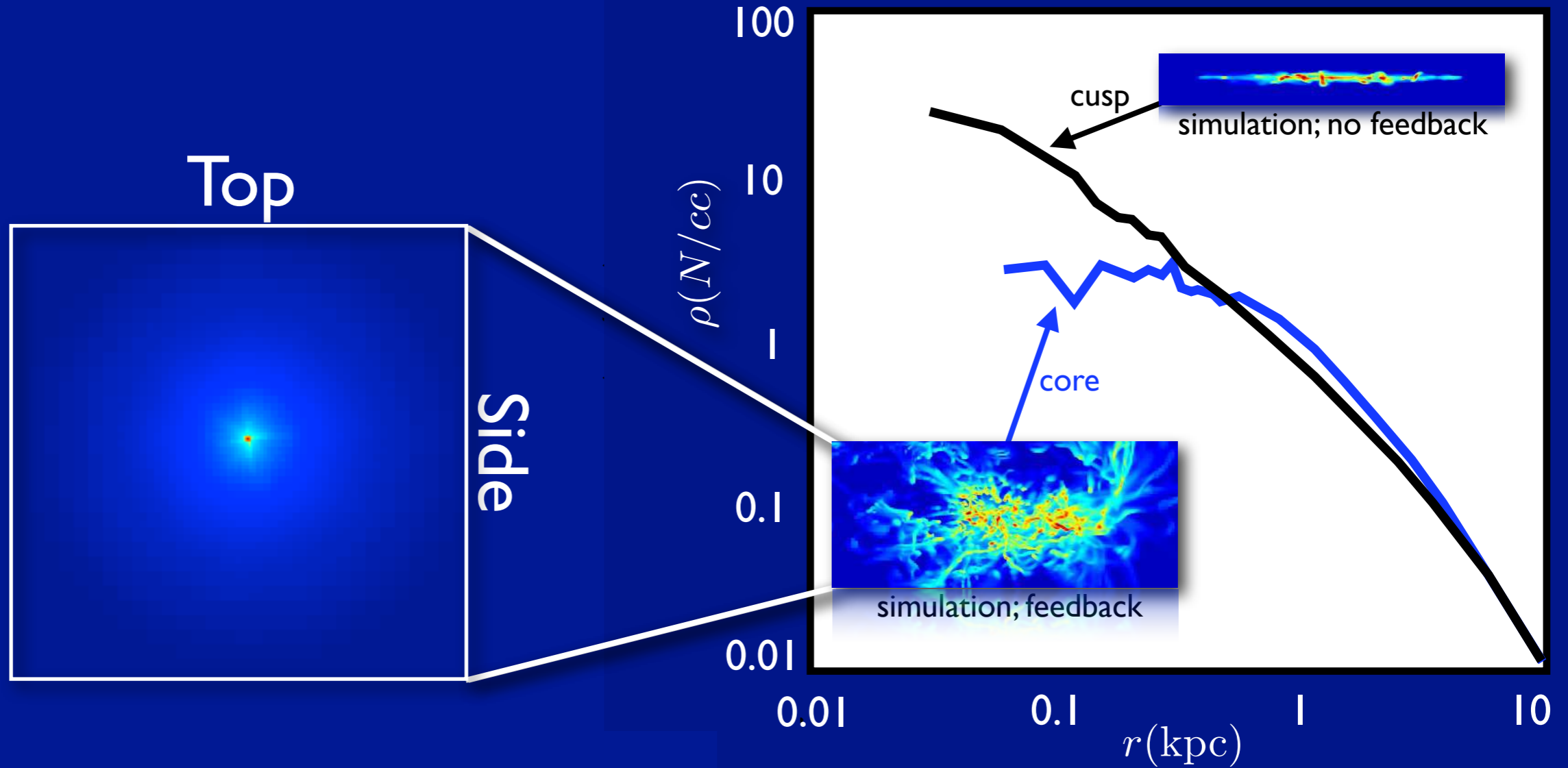
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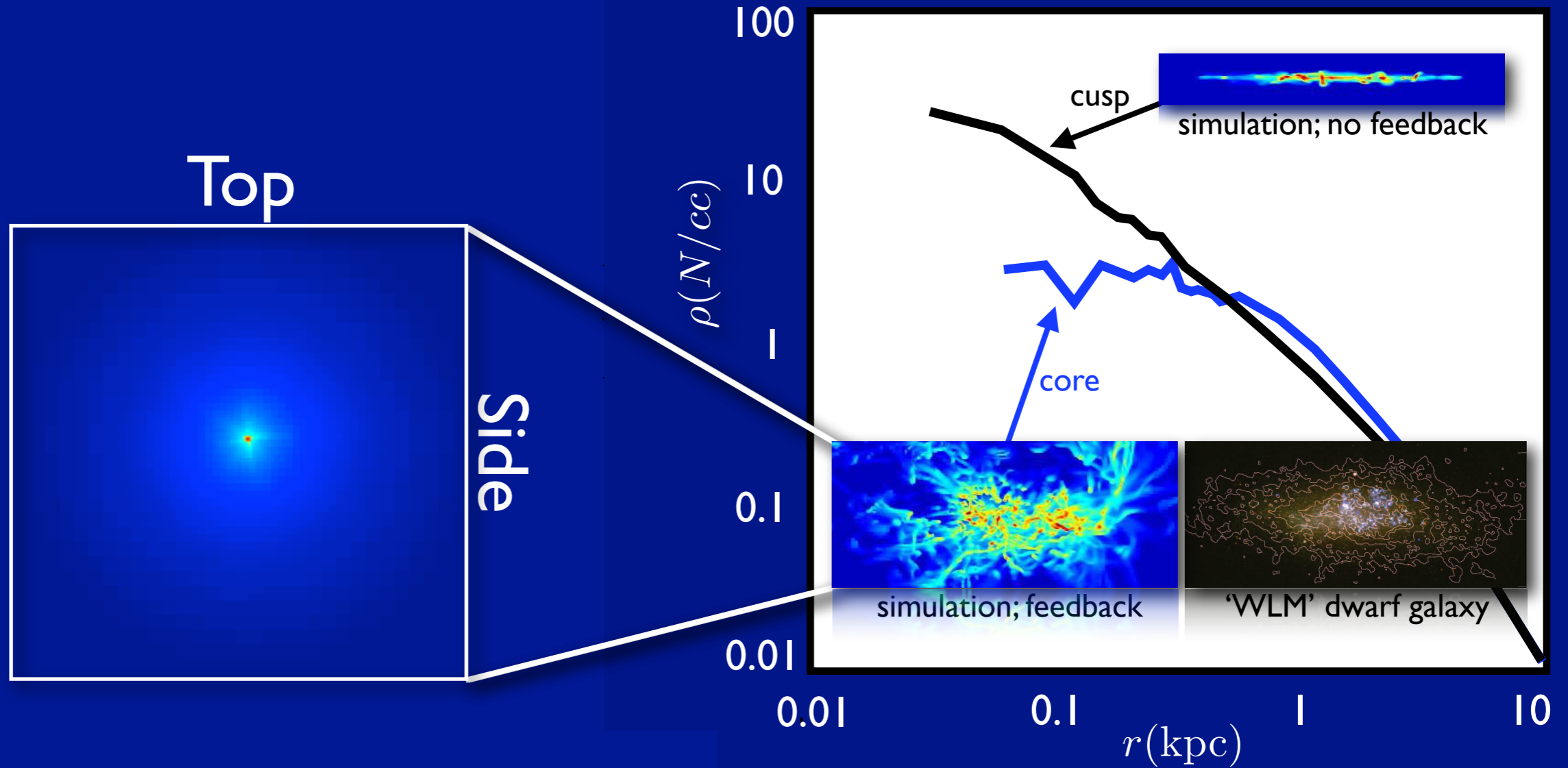
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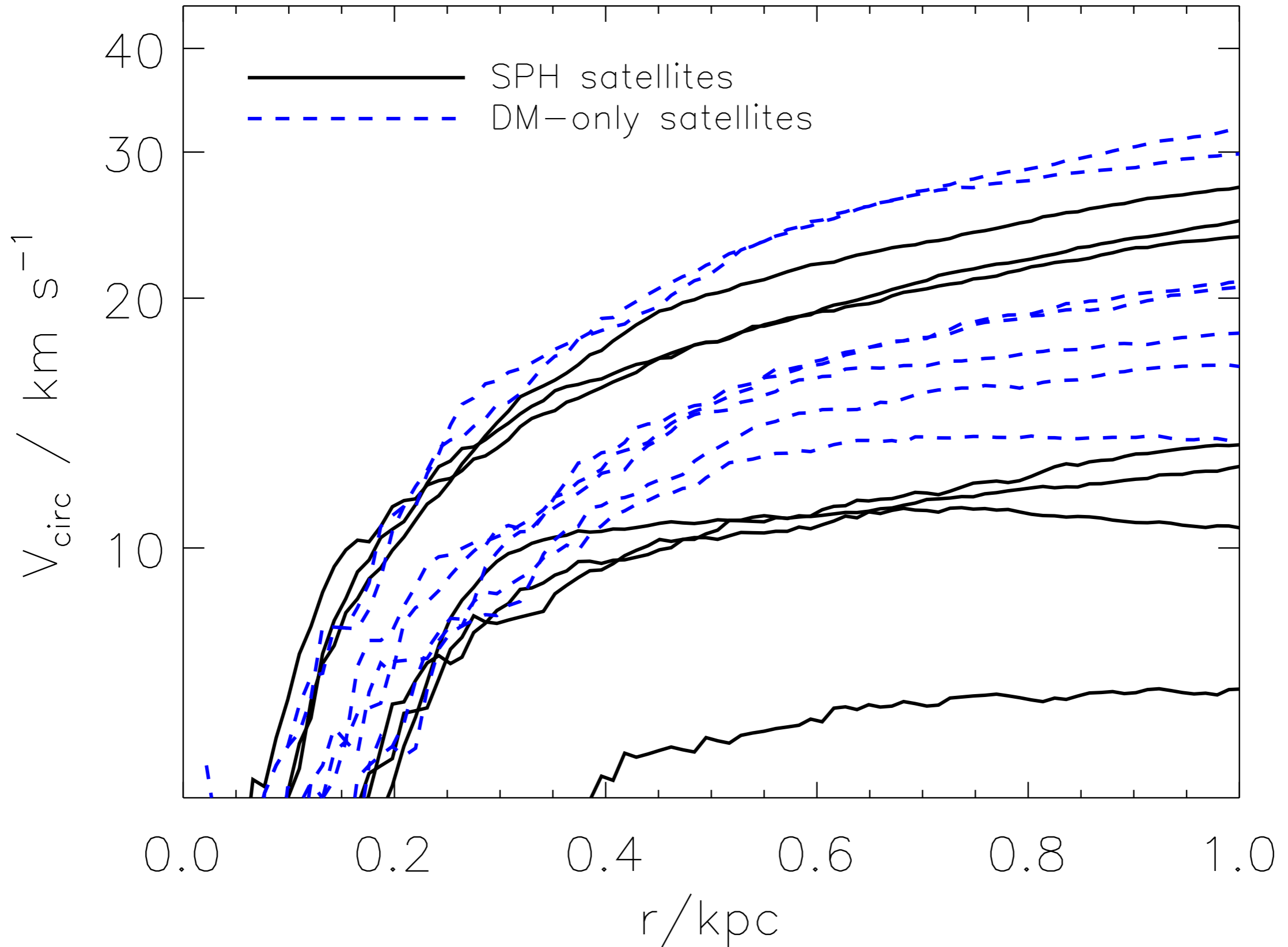
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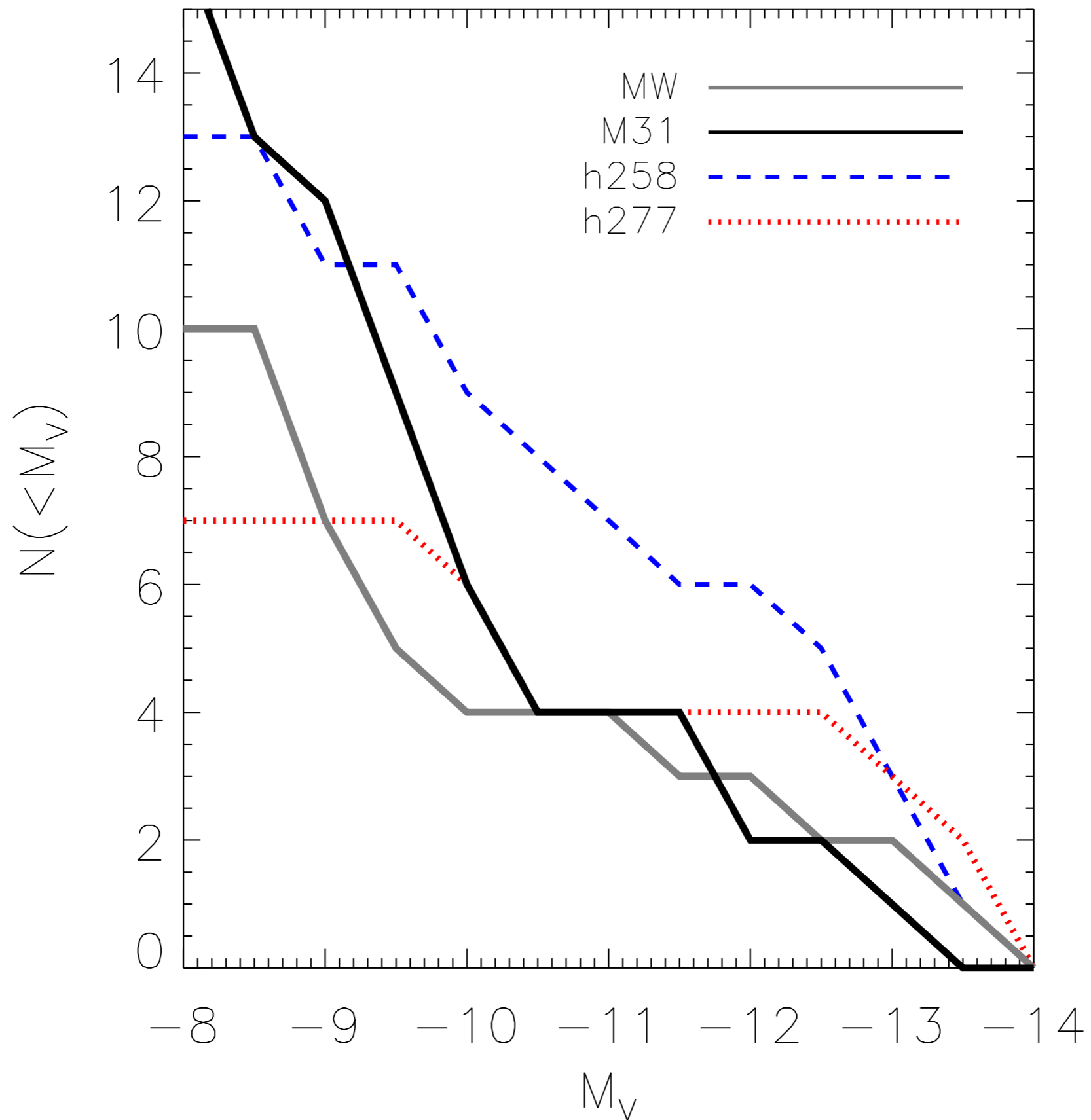
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Zolotov et al. 2012; and see Read et al. 2006; Penarrubia et al. 2010

3. The role of baryon physics | ‘Missing satellites’

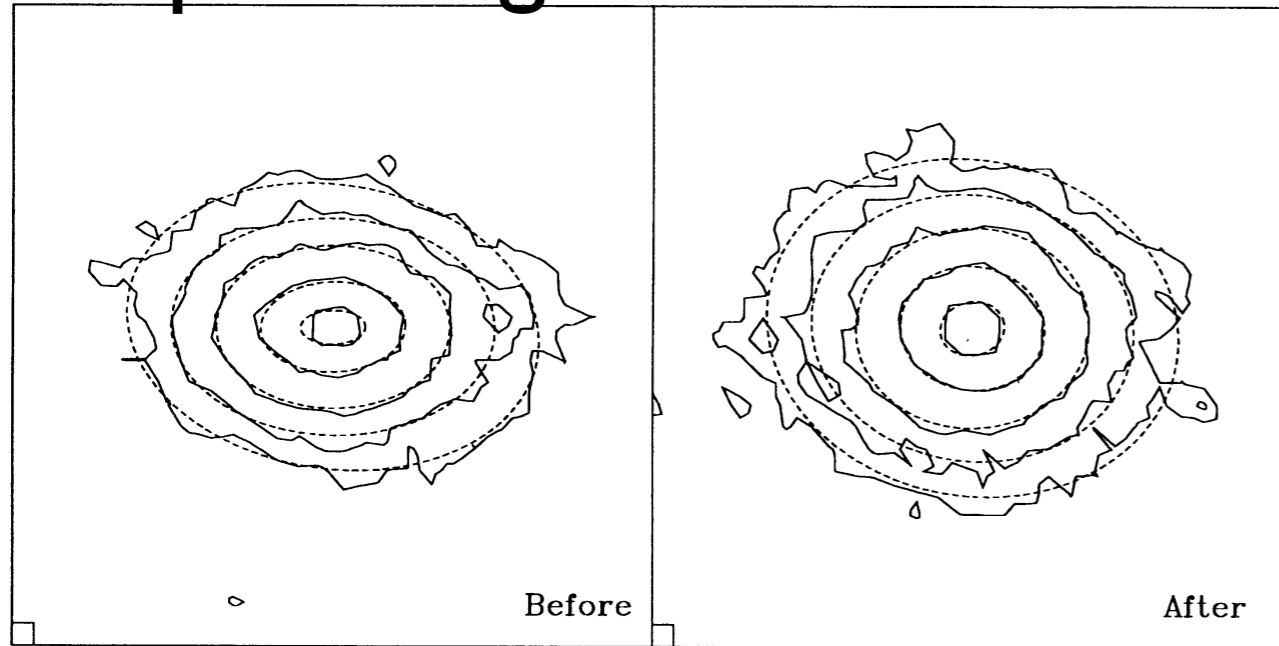


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3. The role of baryon physics | Other effects

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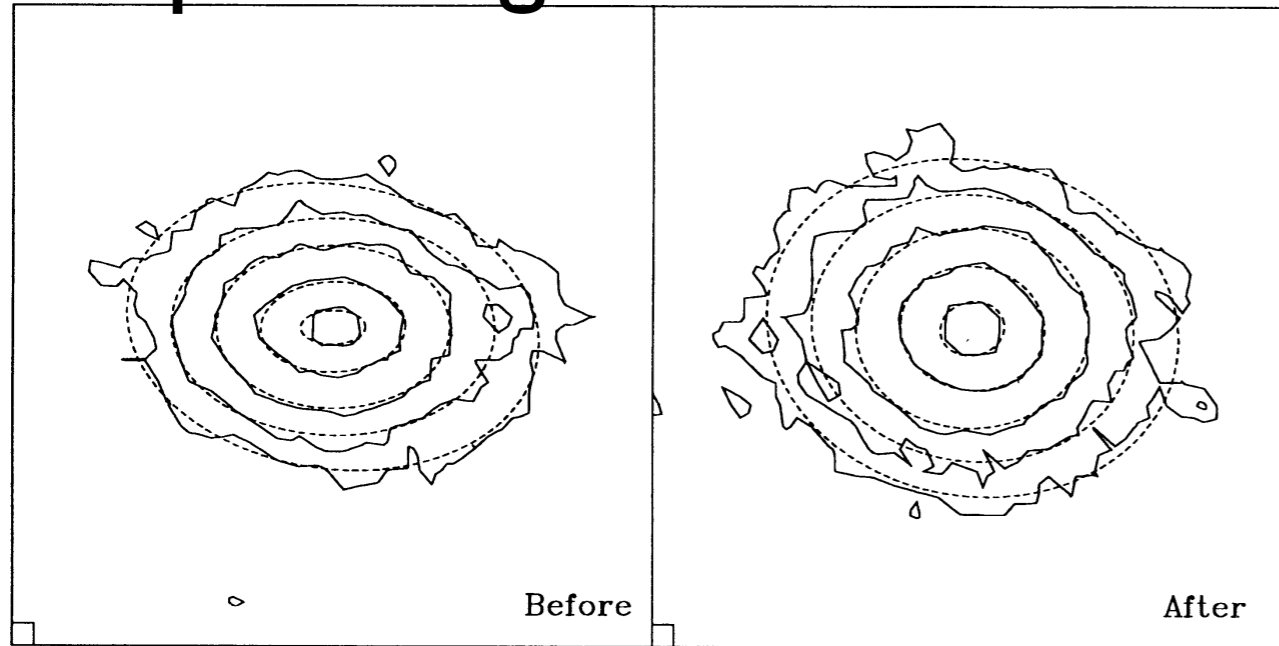
Shape change



Dubinski 1994; Debattista et al. 2008

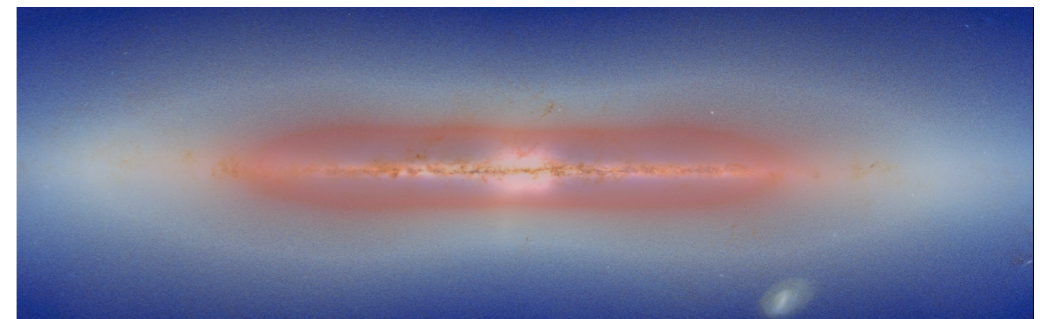
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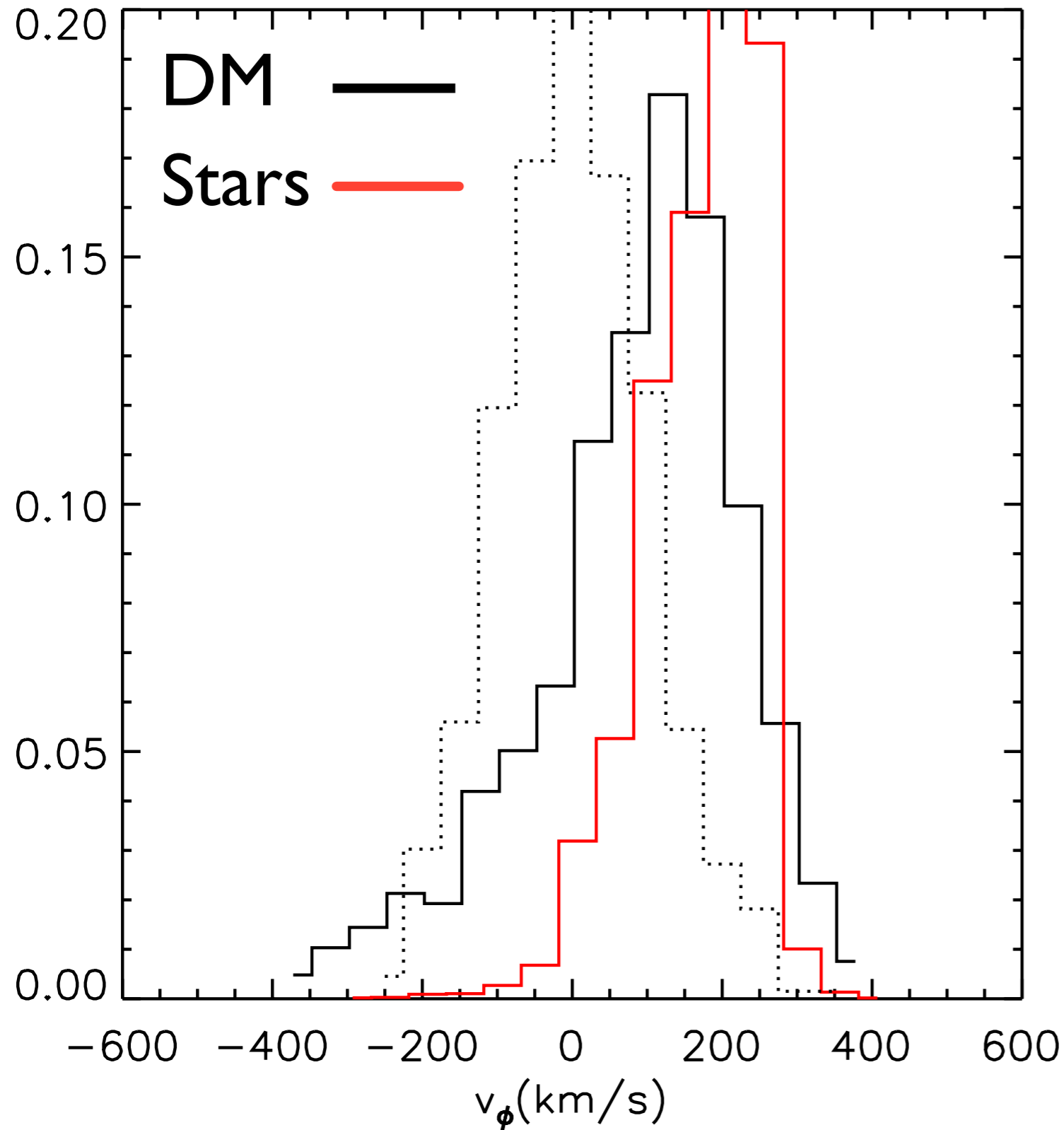
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“Dark discs”

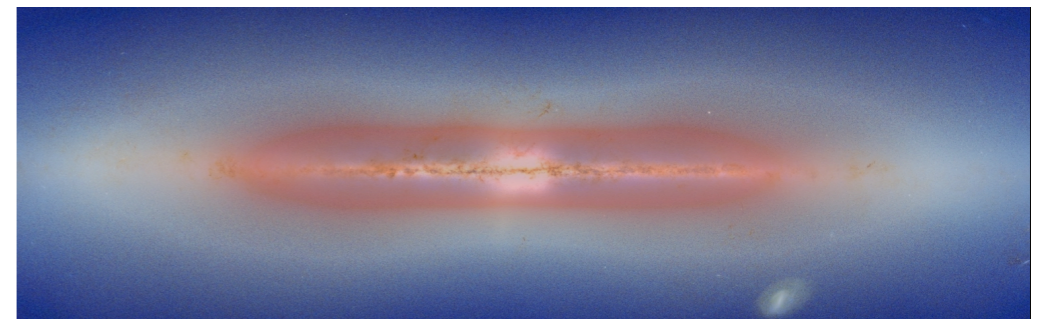


Lake 1989; Read et al. 2008/9

3. The role of baryon physics | Other effects



“Dark discs”



Lake 1989; Read et al. 2008/9

5. Conclusions

- Cold Dark Matter “Dark matter-only” simulations are well converged across different codes.
- Warm Dark Matter simulations converge very slowly. This owes to a mis-match between force and mass resolution. We have developed a proof-of-concept solution.
- Including models for baryons in the Universe can, in principle, significantly alter the results from structure formation simulations:
 - Triaxial “halos” \Rightarrow Oblate/round halos.
 - Cuspy dark matter profiles \Rightarrow Cored dark matter profiles.
 - Cored halos are more easily tidally disrupted \Rightarrow Fewer satellites.
 - An existing stellar disc \Rightarrow An accreted “dark disc”.
- More work is required to determine the true strength and role of baryonic “feedback”.