SIDM at large radii in cluster-sized haloes

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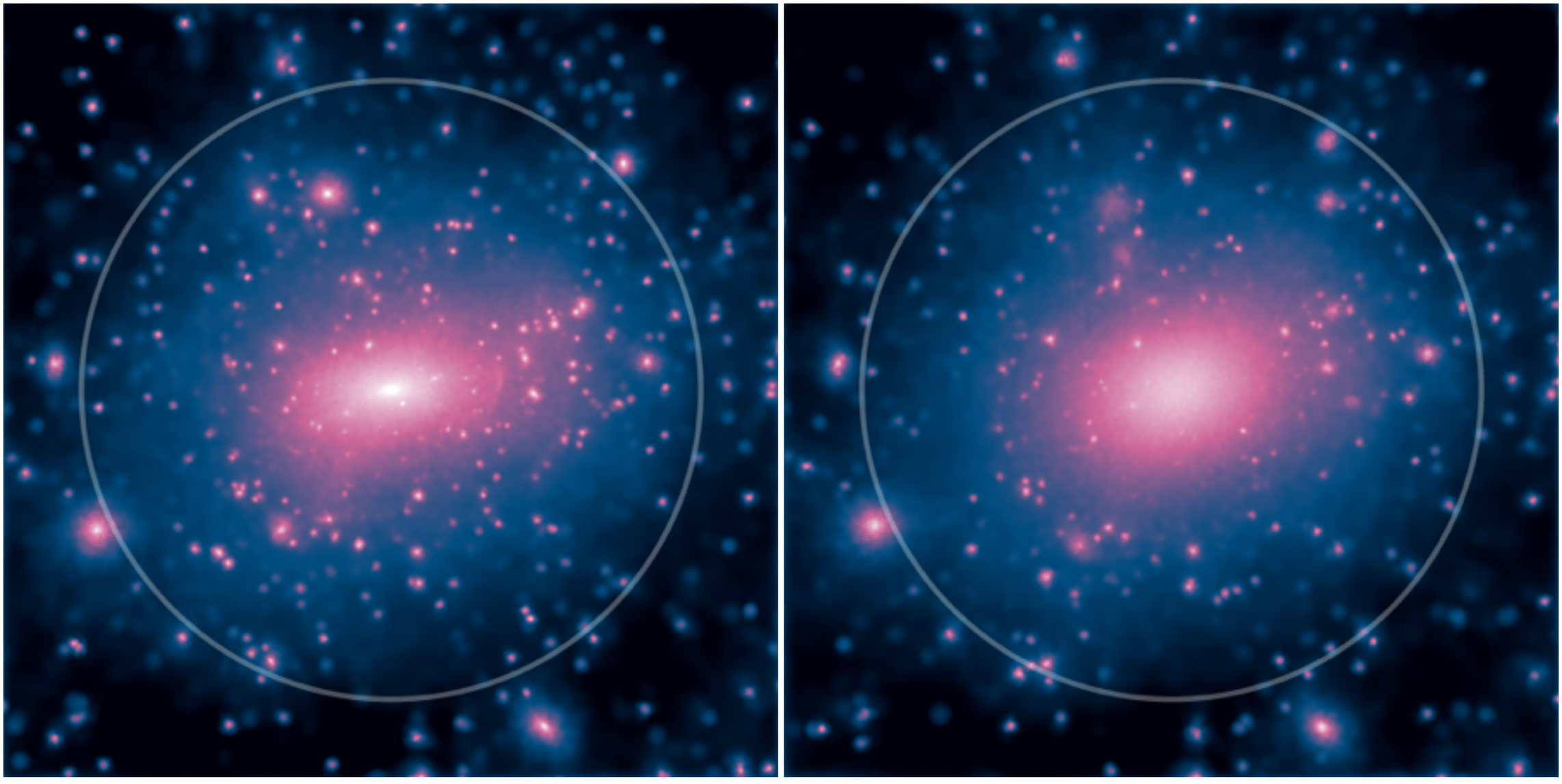
Based on
TB, Zavala, Rapetti, Hansen, Vogelsberger 2017
arXiv:1705.00623

SIDM workshop, NBI, Copenhagen, 01/08/17

CDM

SIDM1



- Baryons vs SIDM?
  - Non-trivial at low radii (previous talk by Mark)
  - Differences at large radii (this talk)

Overview

- Three-pronged attack
  - Halo shapes
  - Density profiles
  - Velocity anisotropy profiles

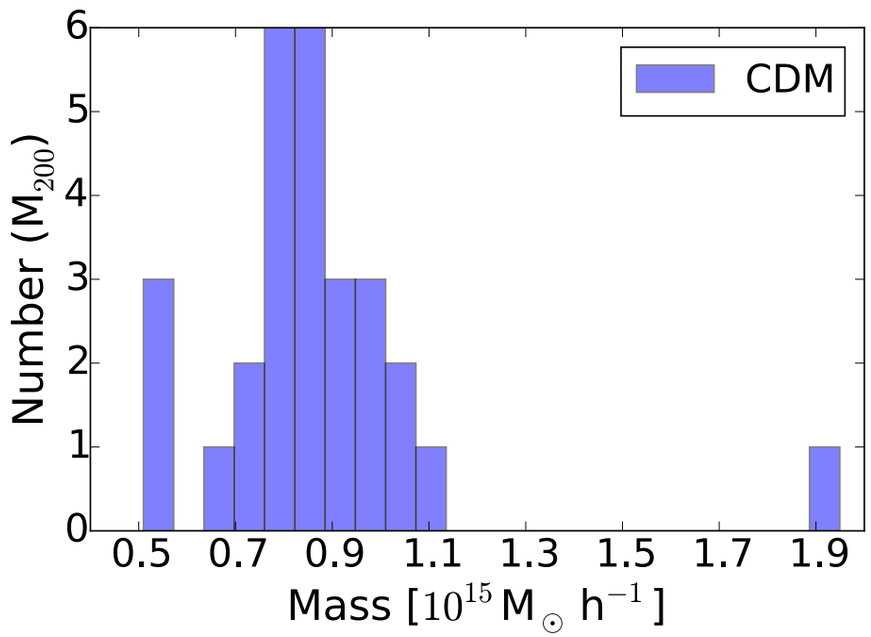
Simulation sample

- Code: AREPO (Springel 0901.4107)

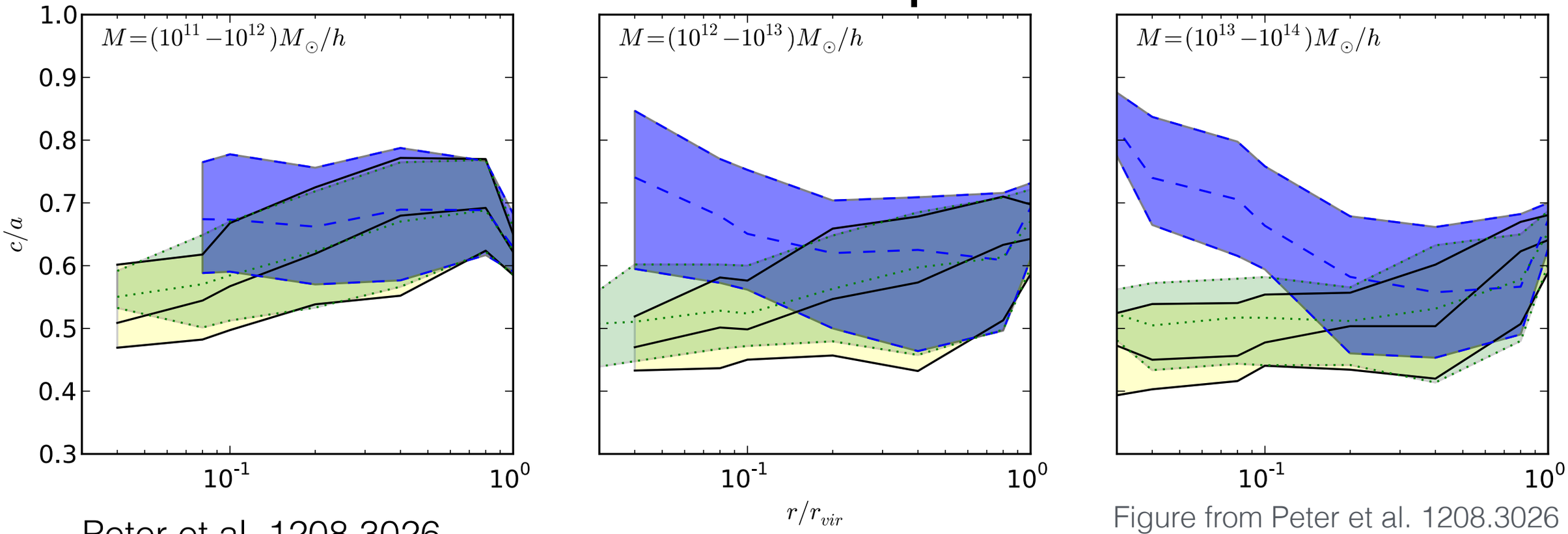
- SIDM Module (Vogelsberger, Zavala, Loeb 1201.5892, Vogelsberger et al. 1512.05349)

- 3x28 relaxed cluster-sized haloes
  - **CDM**
  - **SIDM0.1** $\sigma/m = 0.1\ cm^2/g$ (min. relevant)
  - **SIDM1** $\sigma/m = 1\ cm^2/g$ (~constraint)

- Dark matter only:
  Focus on large radii
  (~ 0.1 R_{200} ~150 kpc/h or larger)



Halo shapes



Peter et al. 1208.3026

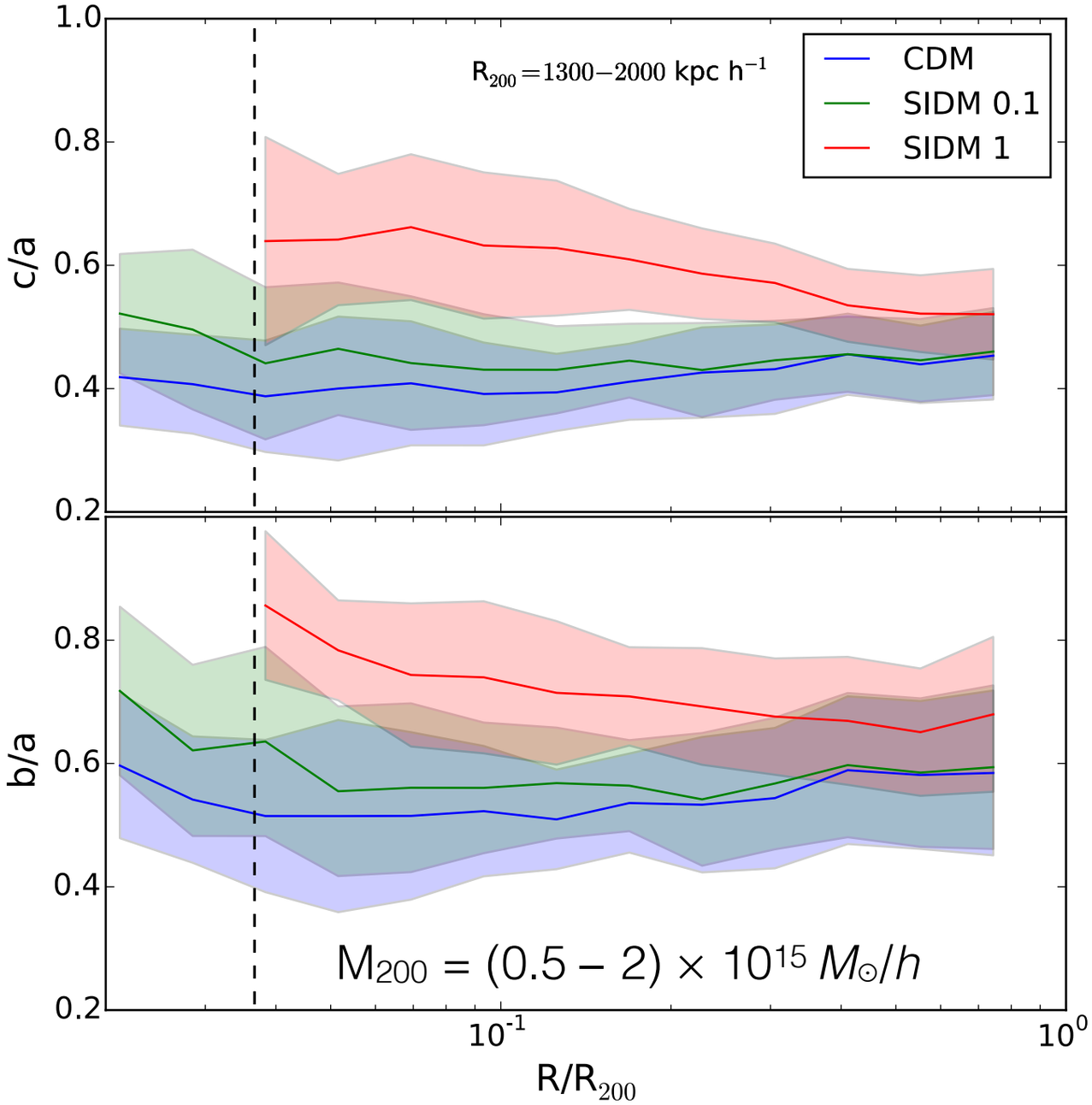
Figure from Peter et al. 1208.3026

- Updated SIDM bounds from halo shapes (David's talk)
- "Low mass" cluster-sized haloes
- More massive ➤ greater difference and up to larger radii
- What about even more massive haloes?

Halo shapes

"High mass" cluster-sized haloes

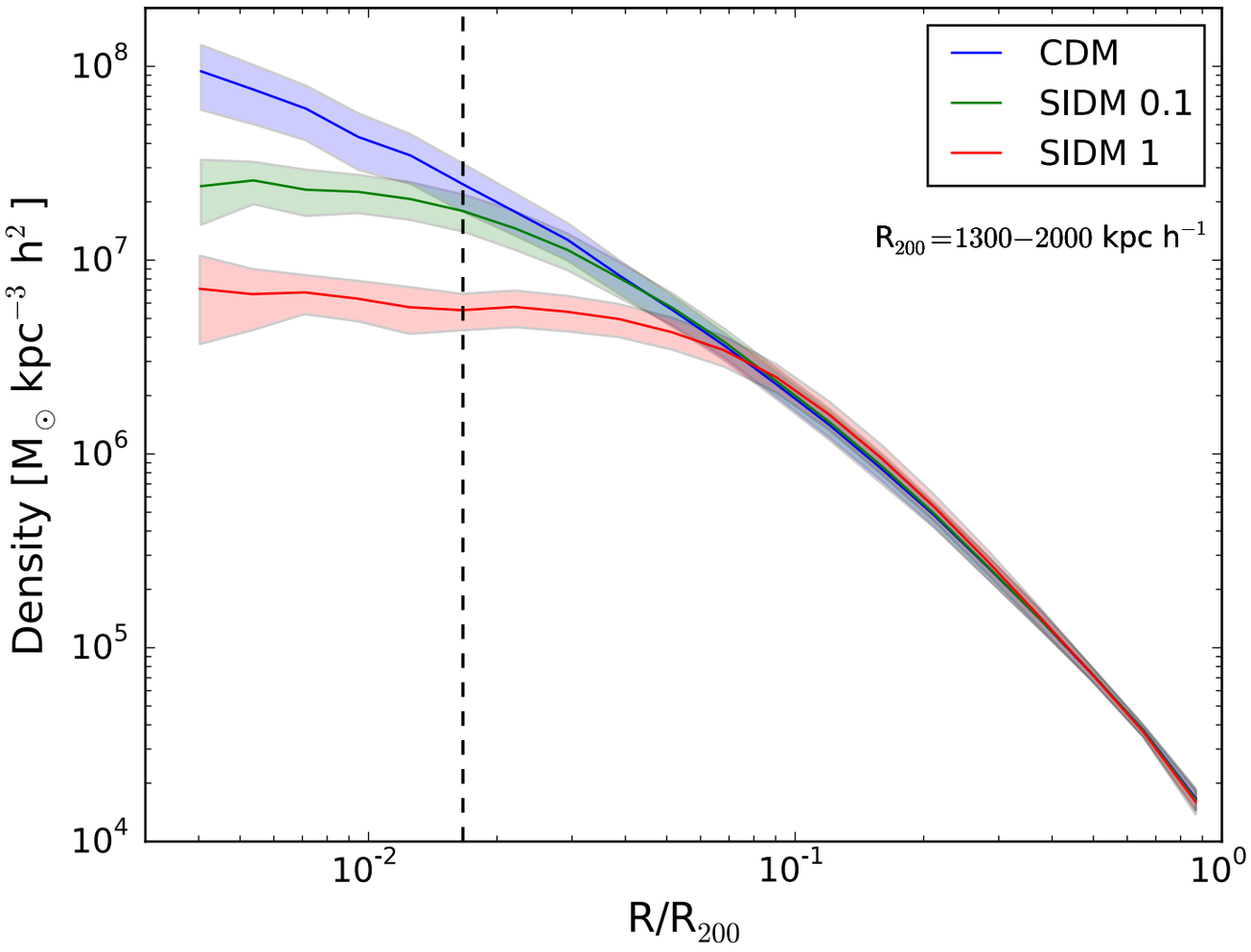
- **SIDM0.1**: Hard target to reach
- **SIDM1**: Clear difference at all radii to 0.3 R_{200} ~ 450 kpc/h!
- Promising, data is available (X-ray, gravitational lensing)
- Challenge: projection effects
- Constraints: work in progress



Density profiles

SIDM creates cored profiles
(e.g. Rocha et al. 1208.3025)

- **SIDM0.1** at resolution level
- **SIDM1** difference up to 0.04 R_{200} ~ 60 kpc/h
- Baryons are important here!
- We need ~ 0.05 – 0.1 R_{200}



Density profiles

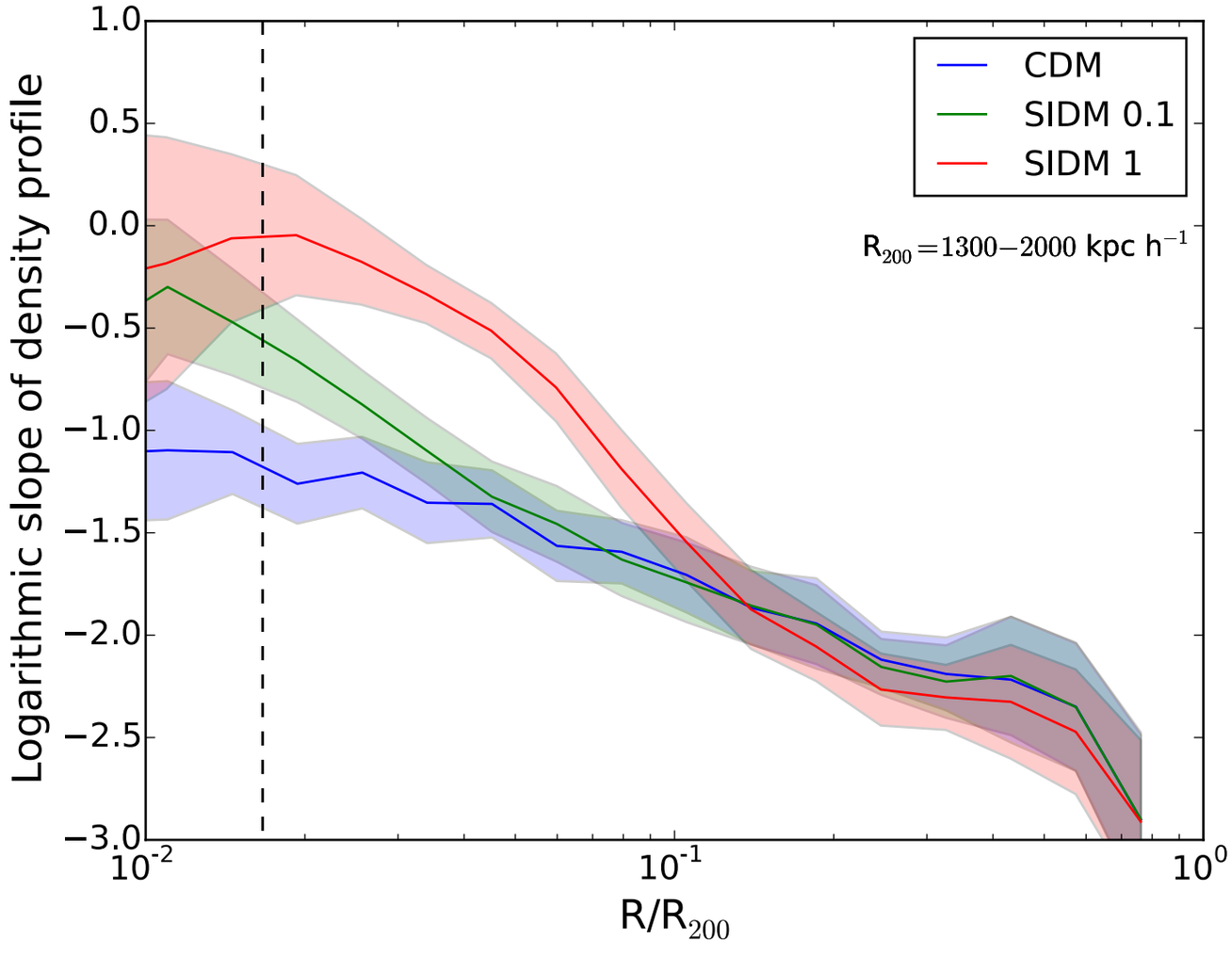
Slope enhances the difference

- **SIDM0.1** at 0.025 R_{200}
  ~ 40 kpc/h (but baryons!)

- **SIDM1** at 0.08 R_{200} ~ 120kpc/h
  - Baryons likely less important
  (e.g. Schaller et al. 1409.8617,
  Peirani et al. 1611.09922)

- Can push constraints
  - May need to consider baryons

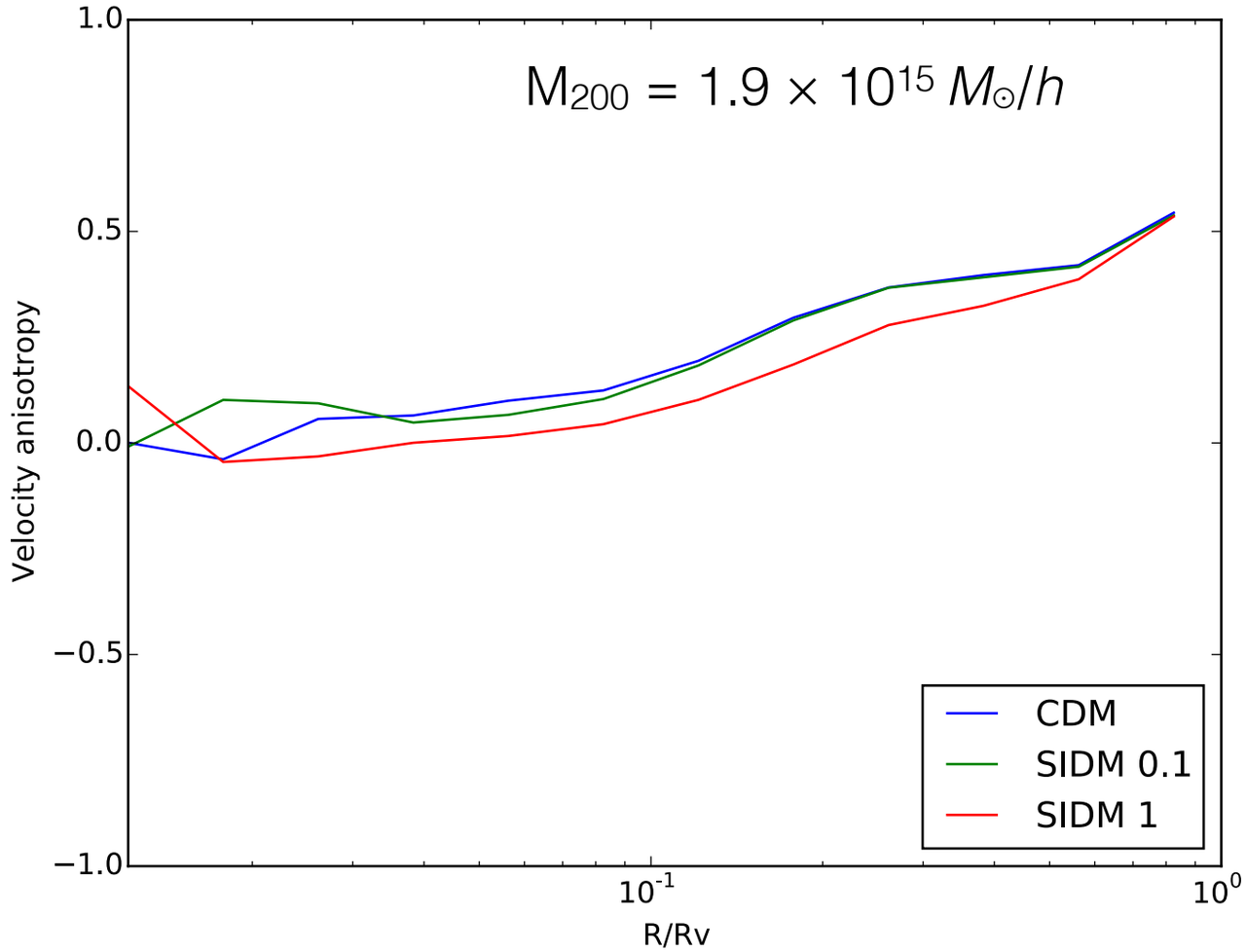
- Newman et al. 1209.1391:
  - Reported deviations from an NFW profile on these scales
  $M_{200} = (0.4 – 2) \times 10^{15}\, M_\odot$



Velocity anisotropy

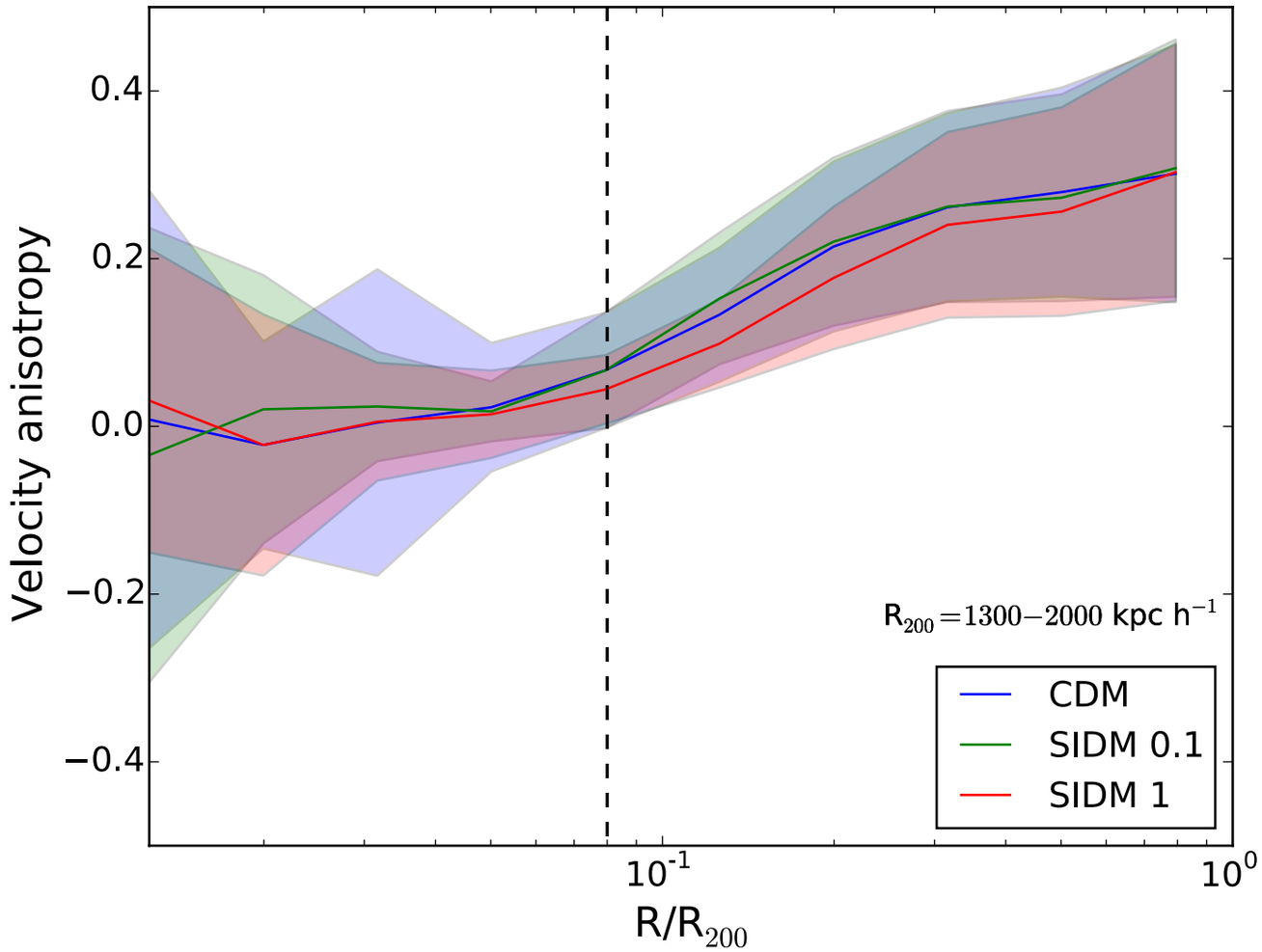
SIDM also affects velocities
(Haibo's talk)

- Isothermal vel. disp. profile
  (Vogelsberger & Zavala 1211.1377)
- This isotropizes orbits
  (Hansen & Piffaretti 0705.4680)
- Velocity Anisotropy
  $\beta(r) = 1 - (\sigma_\Phi^2 - \sigma_\theta^2)/(2\sigma_r^2)$



Velocity anisotropy

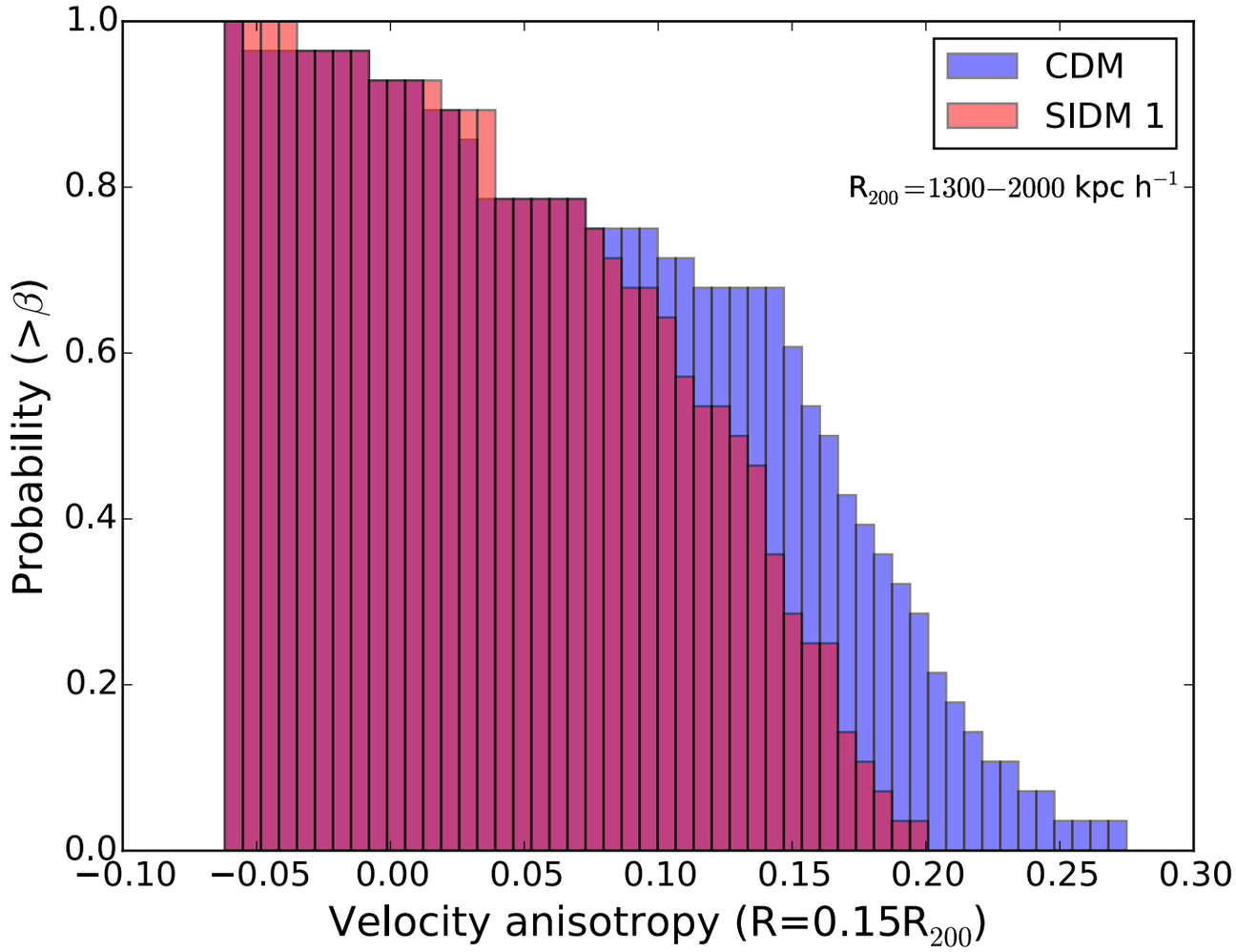
- Hard to resolve differences due to spherical averaging
- **SIDM0.1**: Hopeless
- **SIDM1**: Distribution skewed towards smaller values and 25% narrower
- We can use this!



Velocity anisotropy

Skewed profile

- **SIDM1**: No haloes with $\beta > 0.2$ at 0.15 R_{200}
- **CDM**: 7 out of 28 haloes with larger β
- Can use this to put constraints on SIDM1
- Need: ~60 relaxed galaxy clusters of similar mass
- Constraints: Work in progress



Conclusion

Three-pronged attack

- Halo shapes [on-going]
- Density (slope) profiles [hard]
- Velocity anisotropy [on-going]

Prospects for constraints

- Can improve constraints on SIDM1 at radii where baryons are at least an order of magnitude less important
  (0.08 – 0.3 R_{200} ~ 125-450 kpc/h)
- SIDM0.1 hard target to reach, somewhere between the two?