DSU - December 8th 2022

merging clusters as a testbed for self-interacting dark matter

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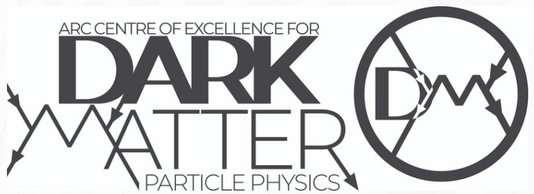


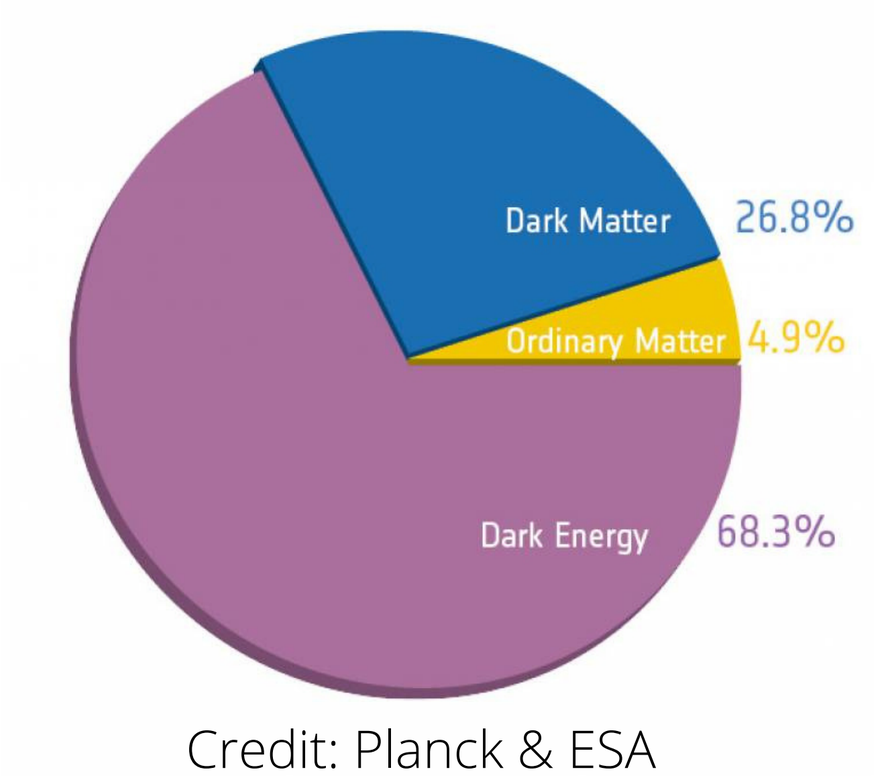
THE UNIVERSITY OF SYDNEY

Durham University
Institute for Computational Cosmology

The ΛCDM model

The standard model of cosmology

- Cosmological constant **Λ**
  ⟶ Dark energy
- **Cold** dark matter (CDM)
  ⟶ **Collisionless**
- Ordinary matter



Credit: Planck & ESA

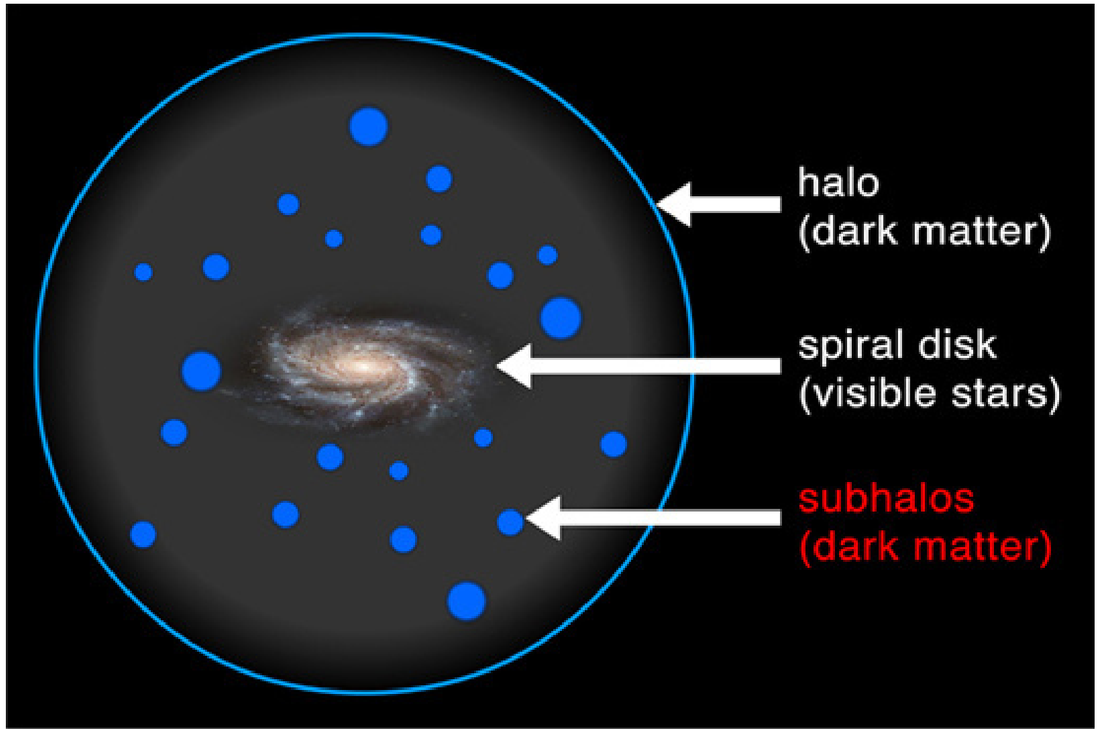
Structure growth

Hierarchical:

Gravitational evolution

Population of DM haloes

Contain a population of subhaloes

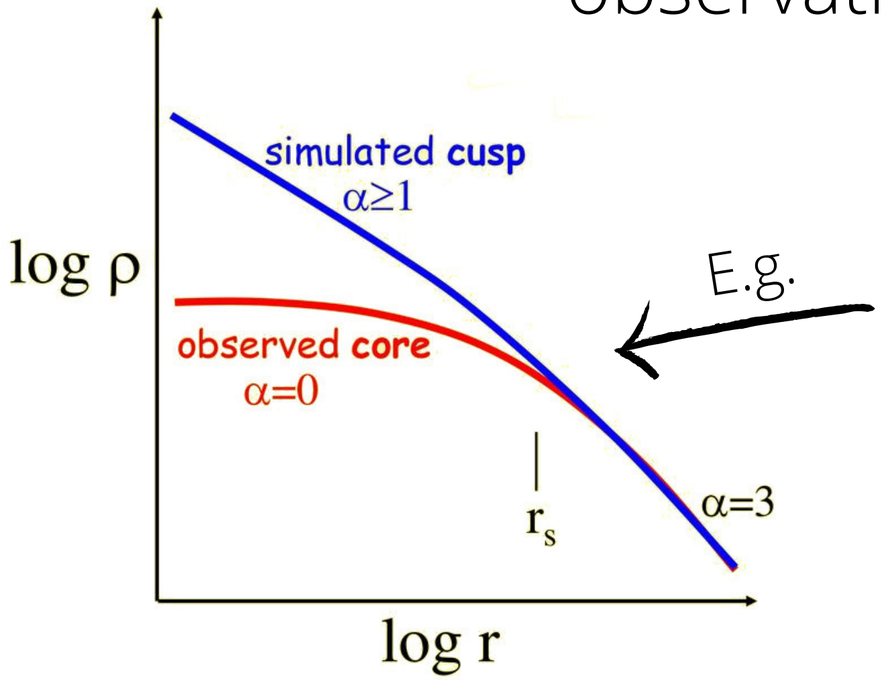


source: https://kids.frontiersin.org/

Galaxies form at centres of (sub)haloes

Discrepancies with CDM

CDM paradigm explains
observations on **large scales** well



E.g. Discrepancies on **subgalactic scales**

Not **collisionless**, but **self-interacting** DM (SIDM)?

Why look at clusters?

Interaction rates scale with density

+

Local velocity dispersion

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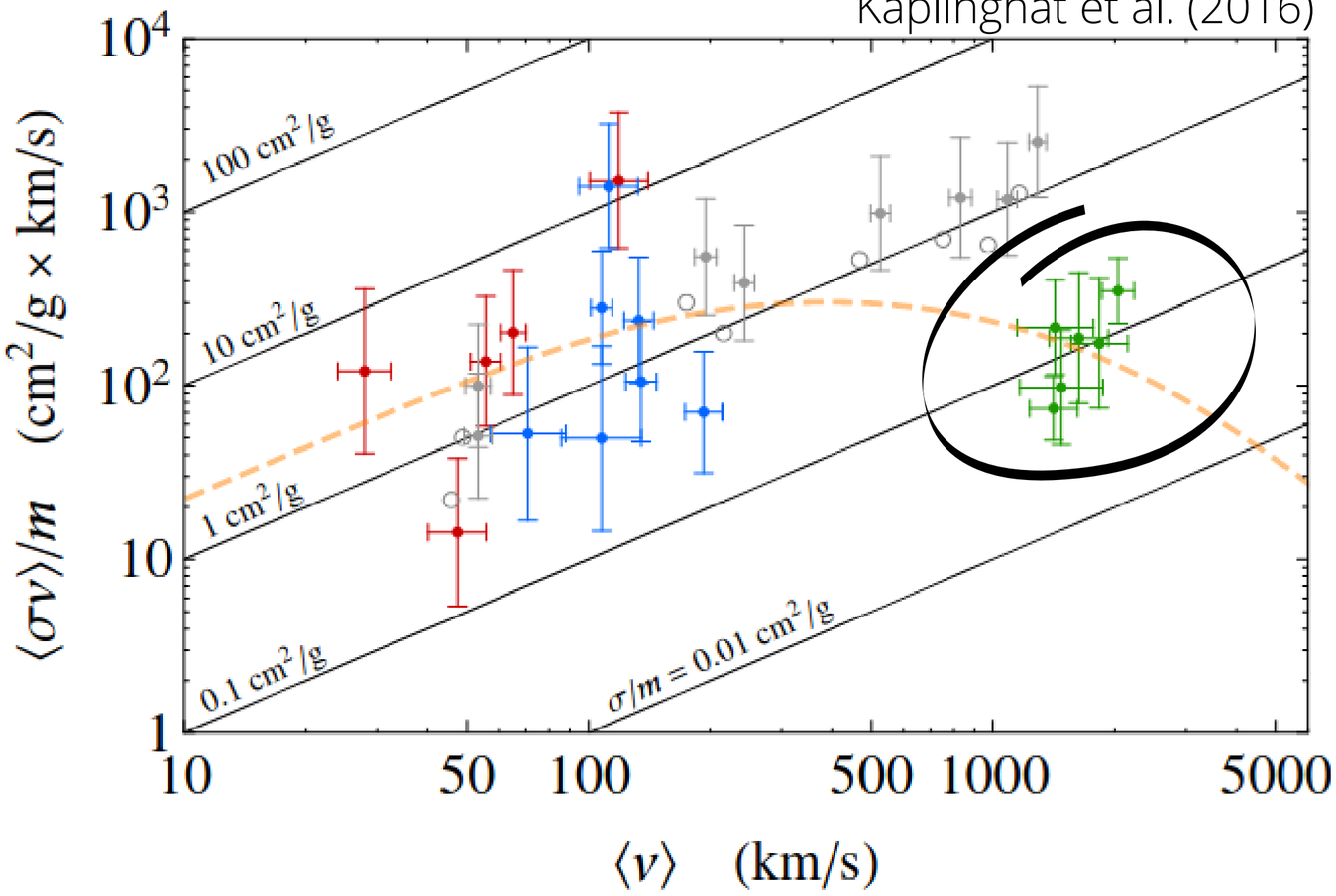
Look at massive systems, i.e. **clusters!**

Kaplinghat et al. (2016)



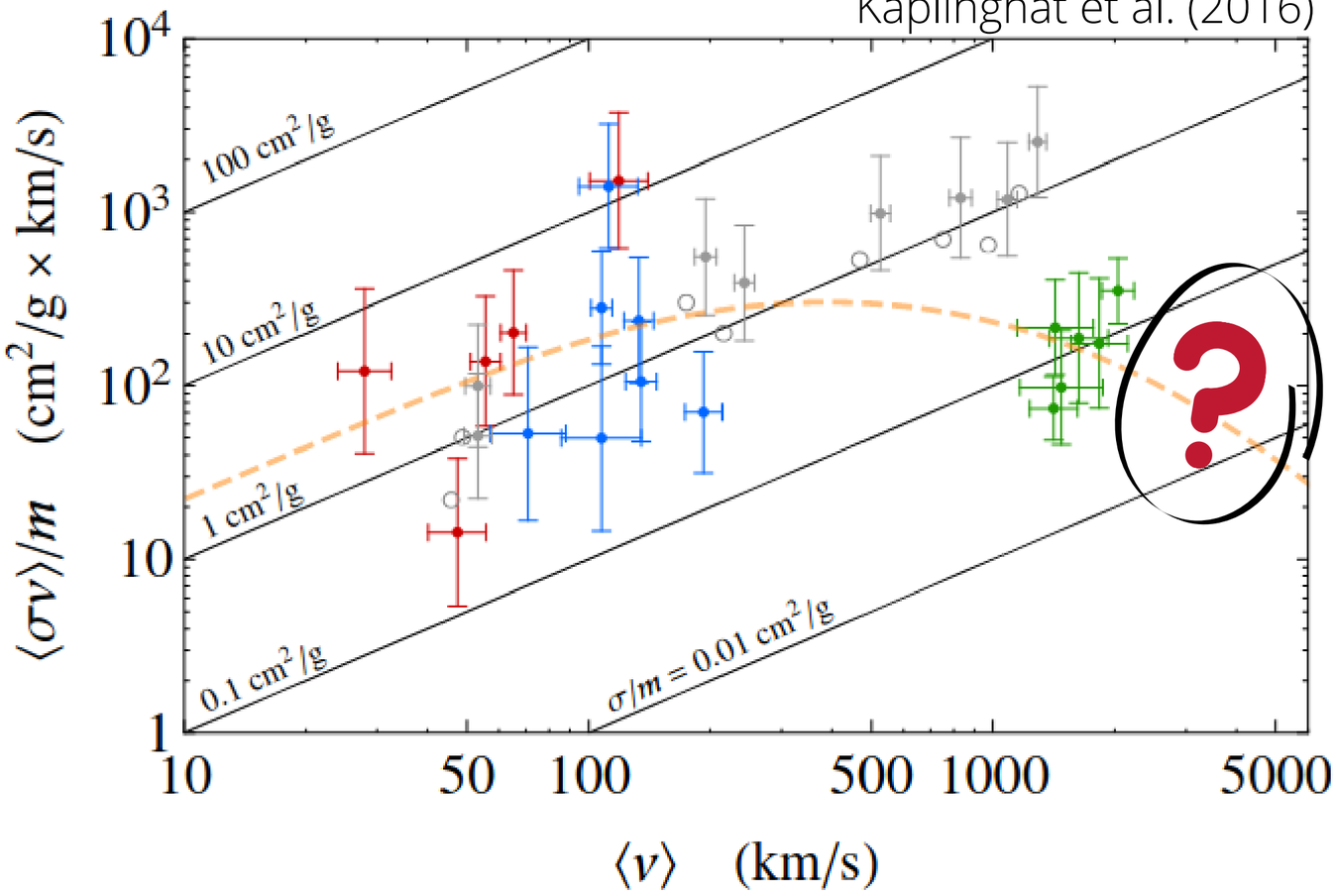
DM distribution can be probed by strong and weak gravitational lensing

Why merging clusters?

even higher DM-DM velocities
than in isolated clusters!

Act as '*cosmic colliders*'

Kaplinghat et al. (2016)



Merging clusters as cosmic colliders

Galaxies: collisionless test particles

Gas: dissociated through ram pressure

CDM:

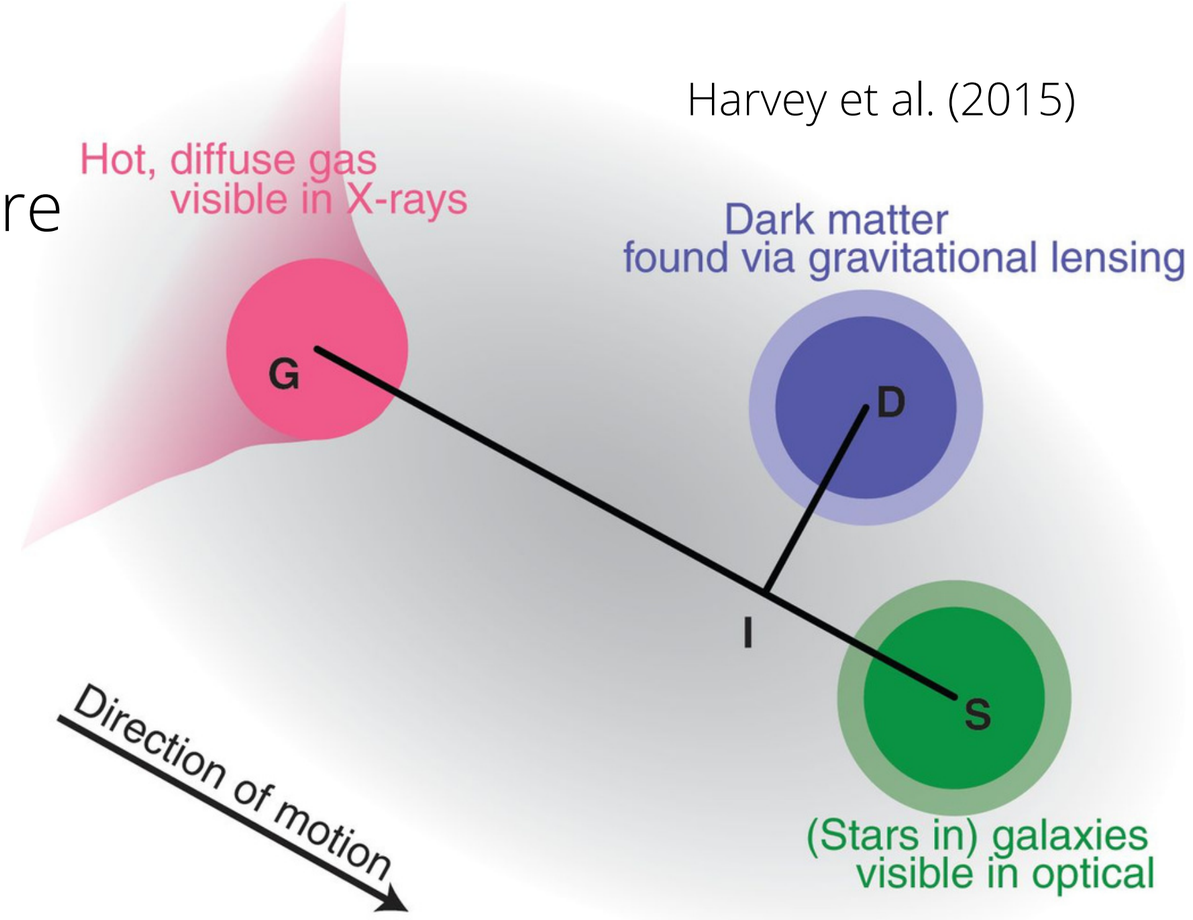
DM remains incident with galaxies

SIDM:

Drag from self-interactions offsets

DM from galaxies

Harvey et al. (2015)



This work

Look at offsets of DM and galaxies/stars in simulated merging clusters

offsets of centres of particle distributions:
shrinking-spheres method

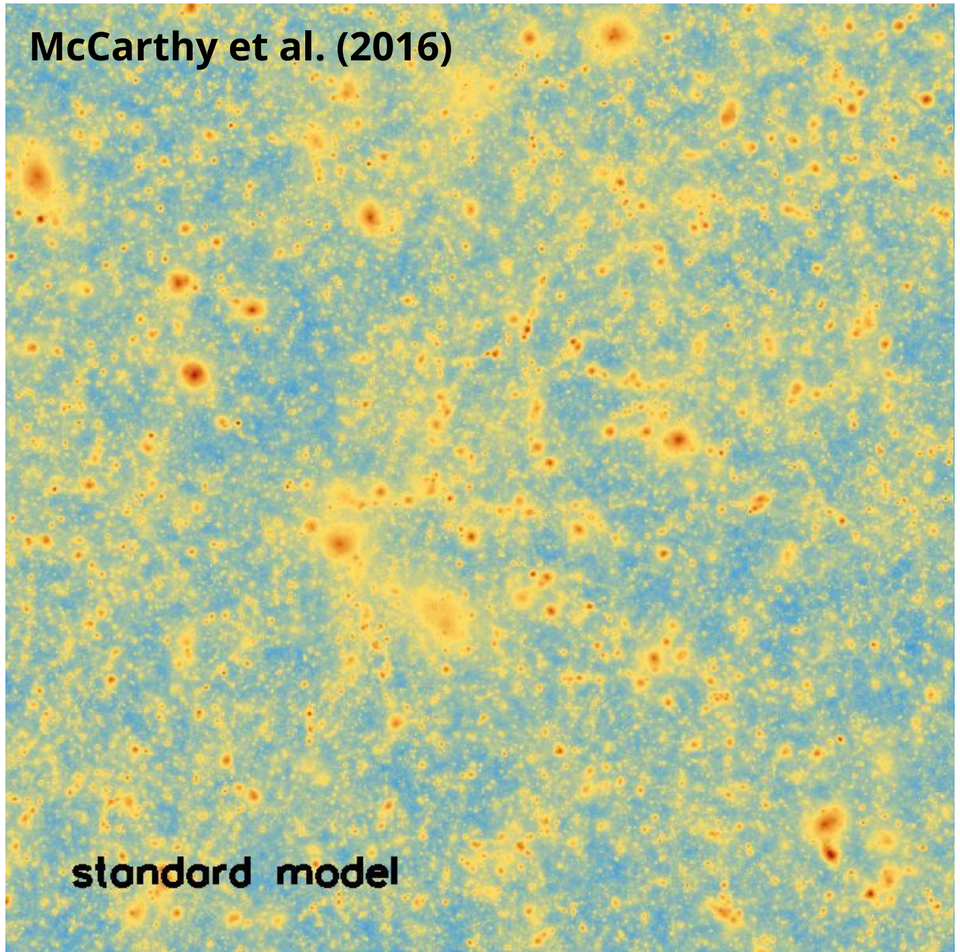
(not really...)

300 most massive clusters with subtructures > 5% cluster mass

<u>Is there any difference in the CDM and SIDM sims?</u>

Simulation data

BAHAMAS (**BA**ryons and **HA**loes of **MA**ssive **S**ystems)



400 Mpc/h box
run with CDM & SIDM physics

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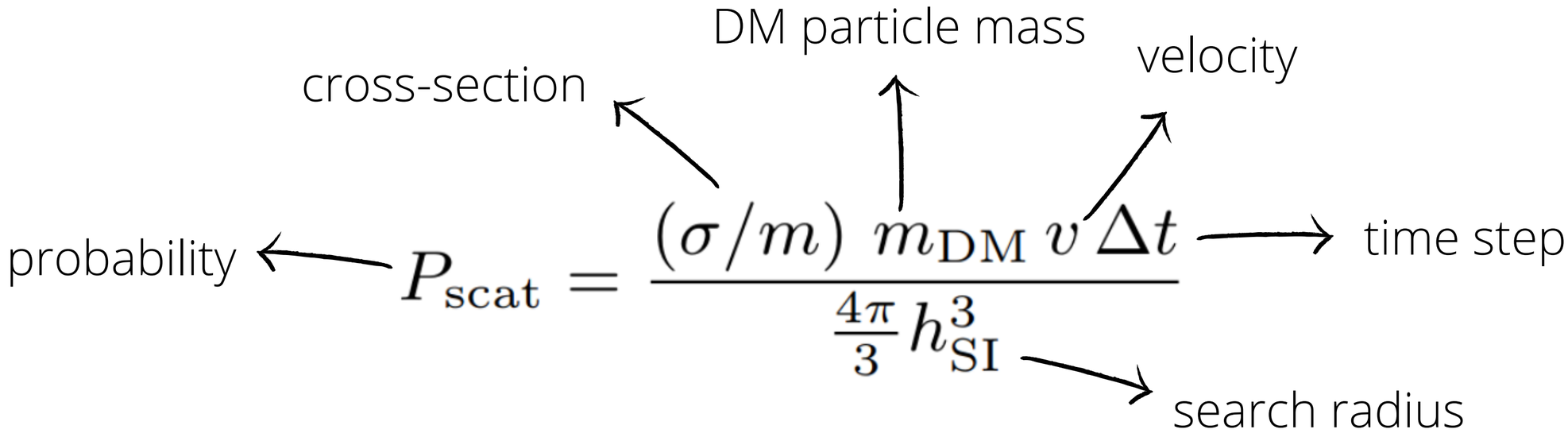
velocity *independent* cross-section:
$\sigma/m = 0.1, 0.3, 1.0\ \mathrm{cm}^2/\mathrm{g}$

DM particles mass: $5.5 \times 10^9 M_\odot$
2×1024^3 particles

Implementation of self-interactions

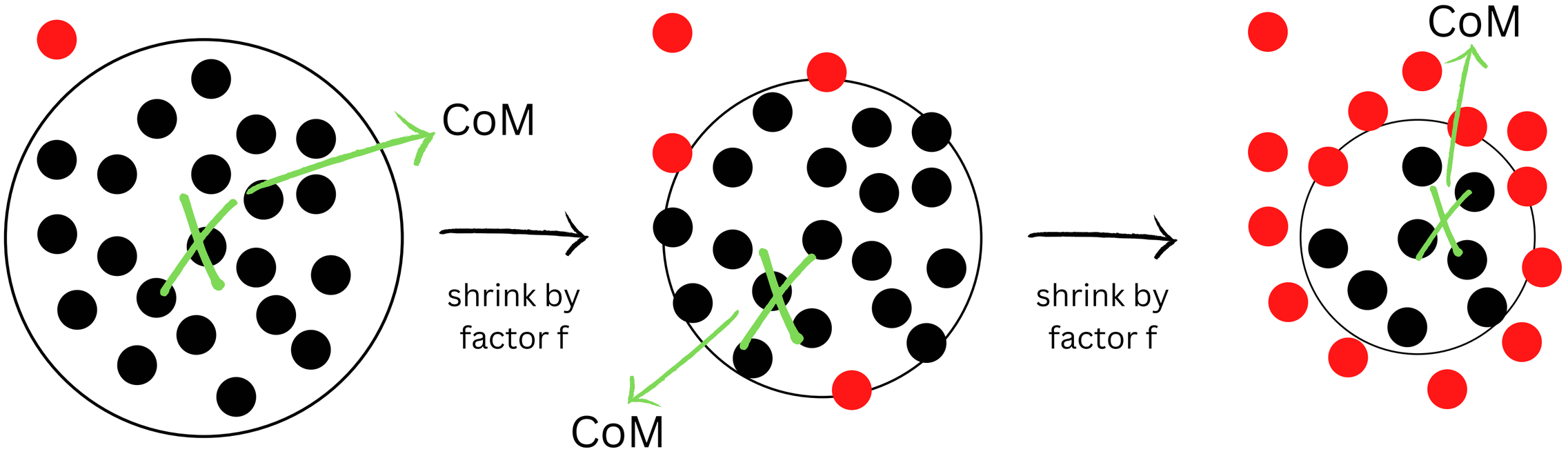
<u>At each time-step:</u>

- DM particles search for neighbours within a radius h_{SI}
- Scatter isotropically with probability:



Robertson et al. (2017)

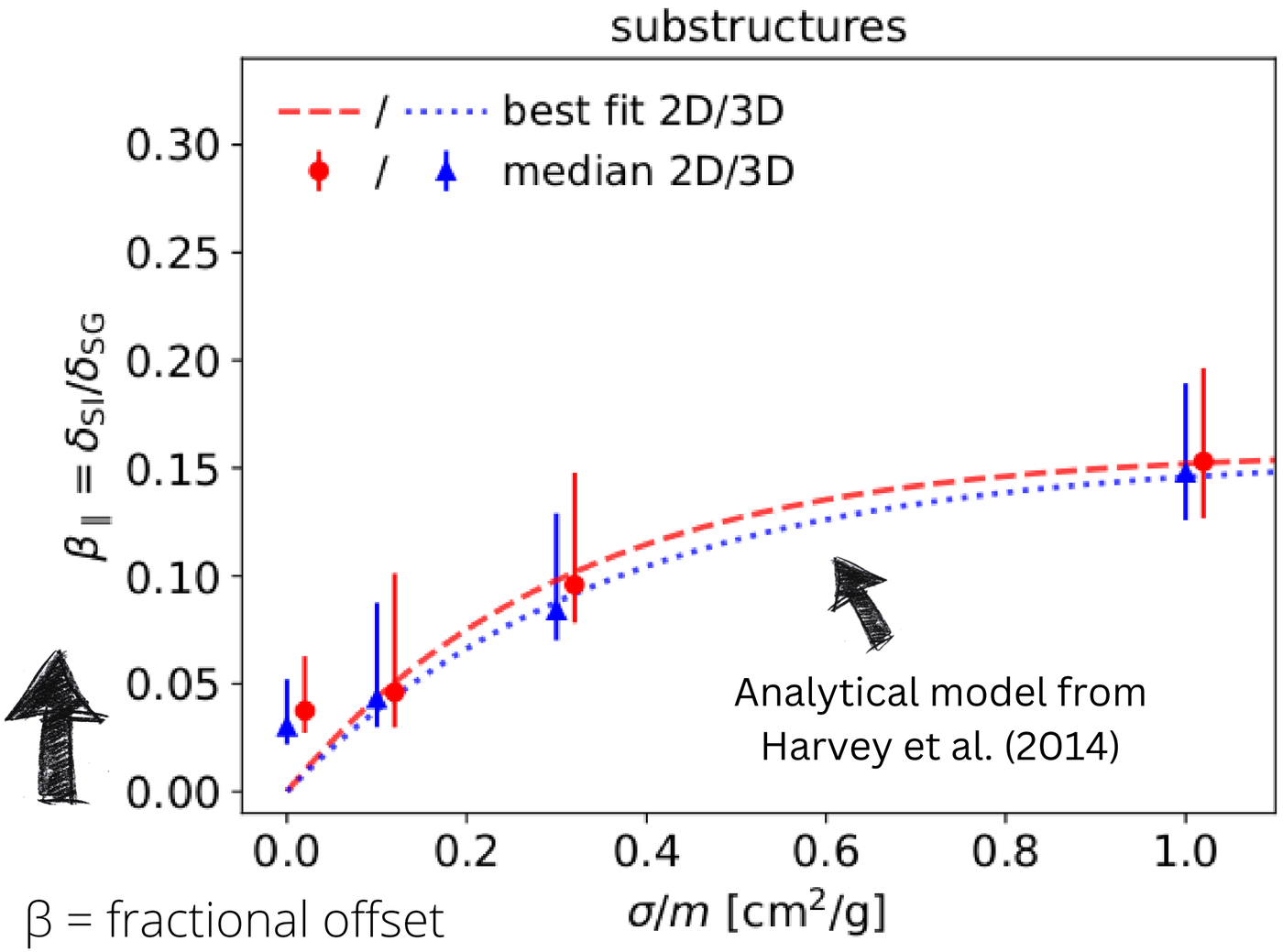
The shrinking-spheres method



shrink sphere by a factor *f*
until reaching a limit

e.g. tolerance, number of particles, final radius

Offset vs. cross-section



β = fractional offset

Offset increases with cross-section!

But CDM non-zero?

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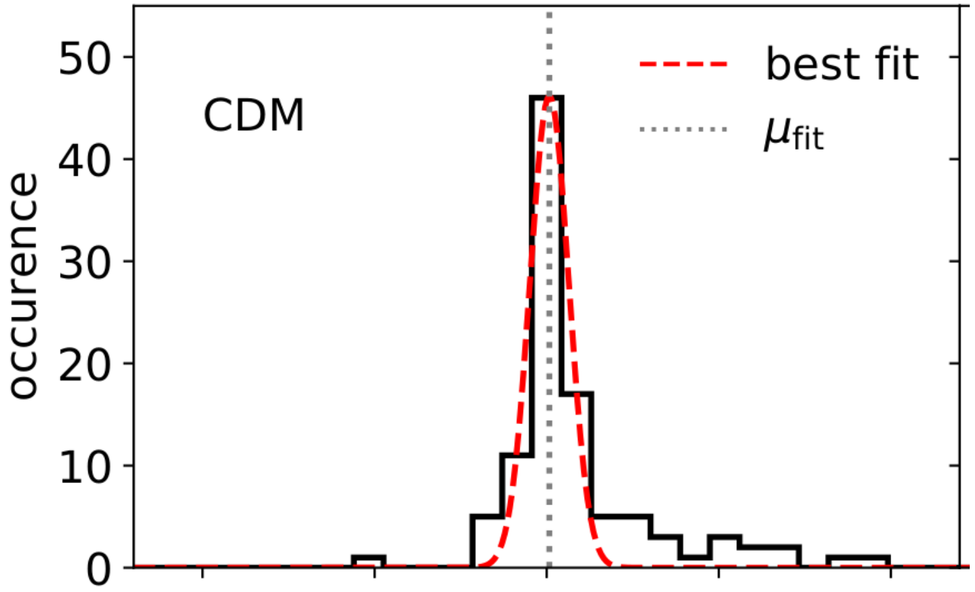
Physical or systematics?

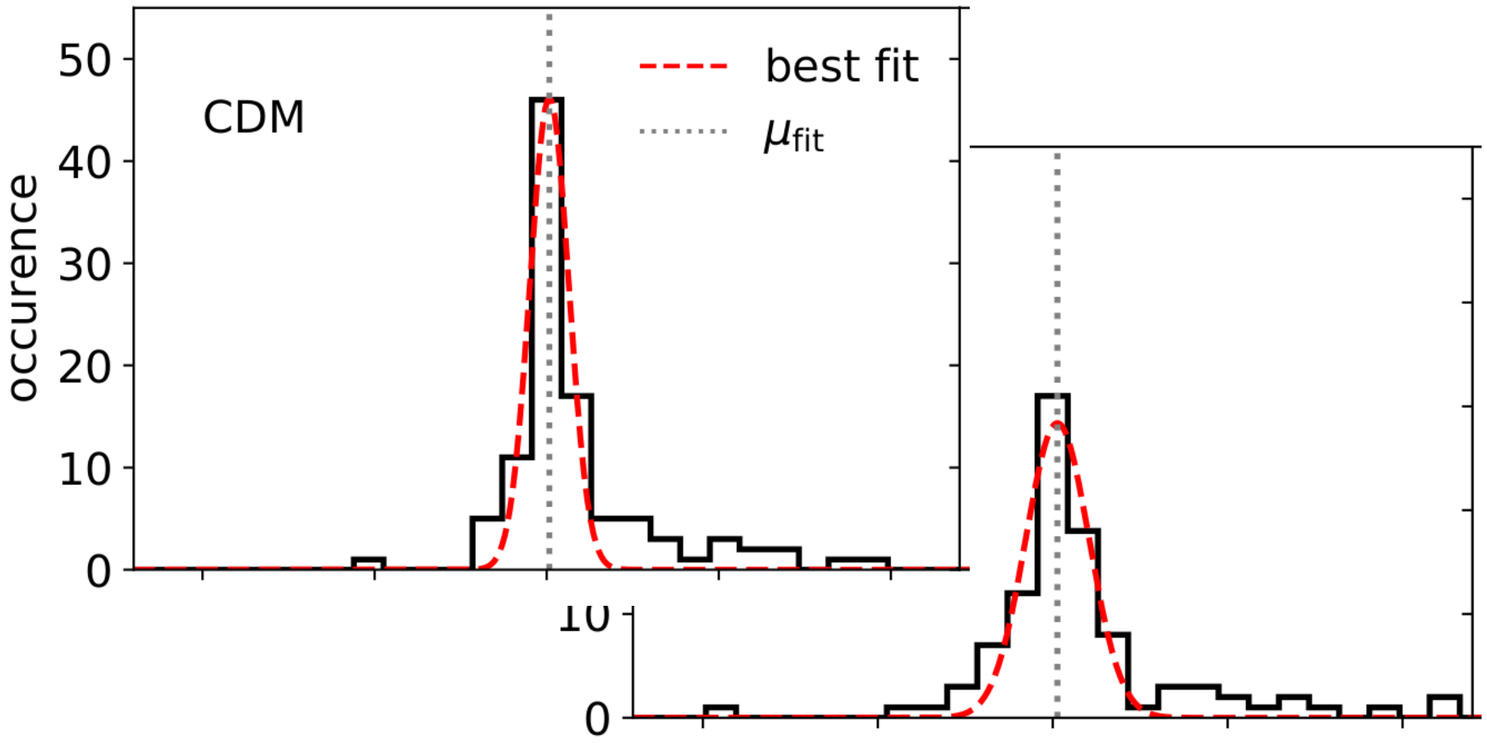
Widths of offset distributions



Distributions are for offsets in cluster haloes

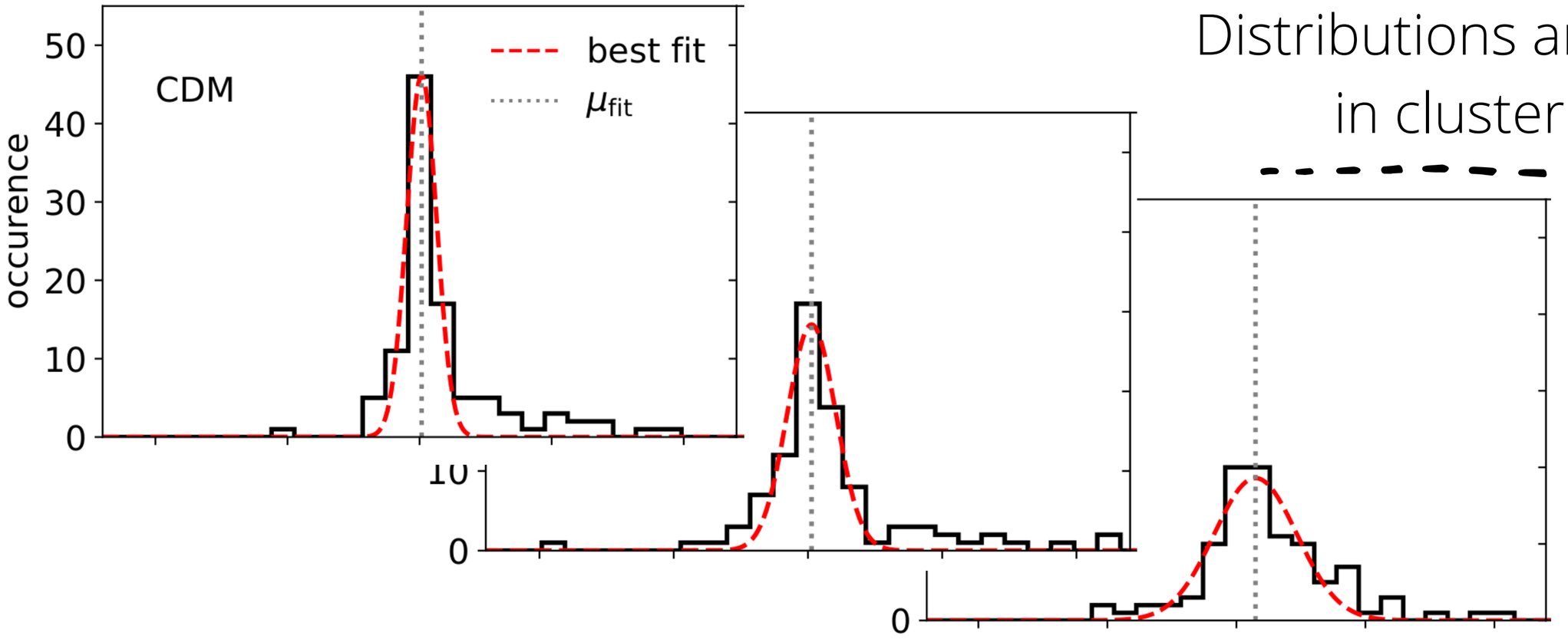
Gaussian fit to histograms

Widths of offset distributions



Distributions are for offsets in cluster haloes

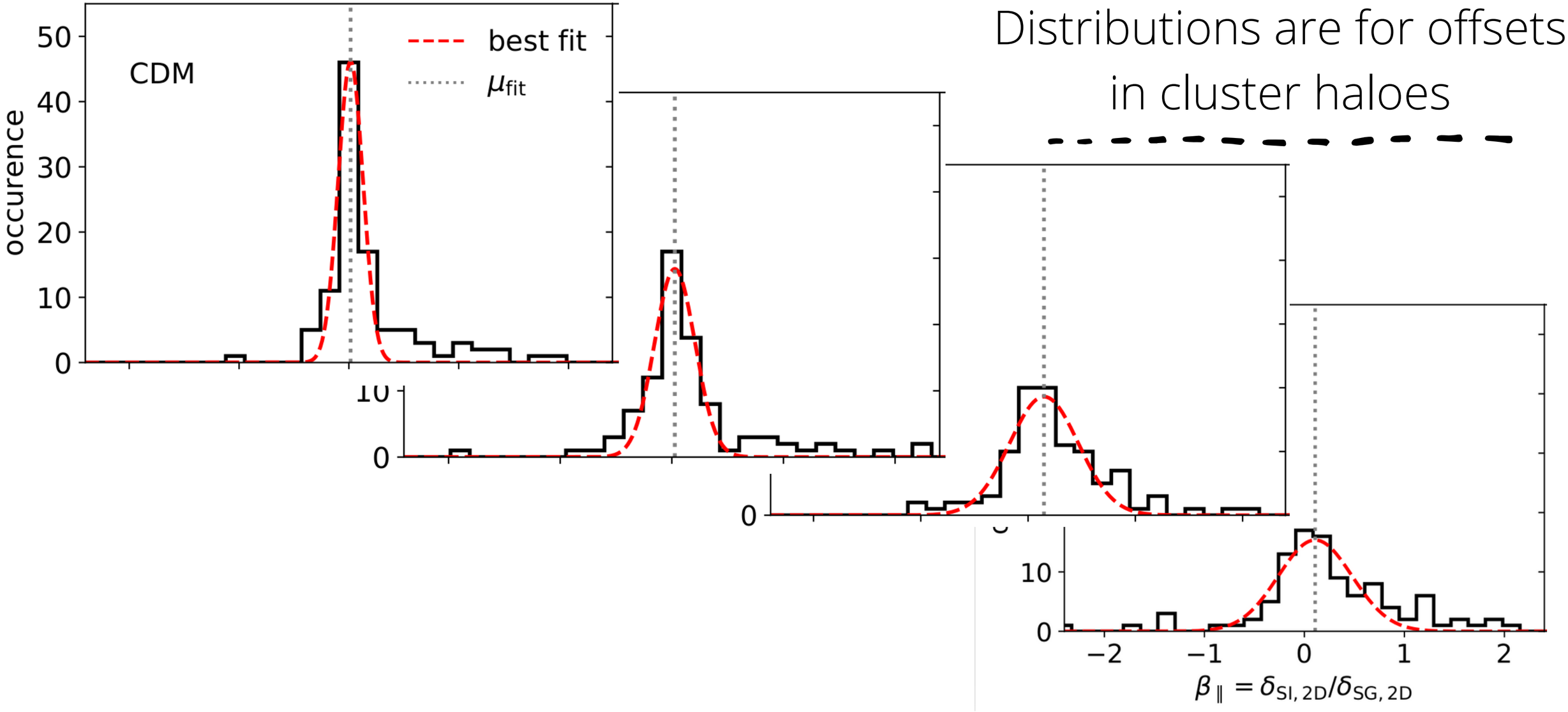
Widths of offset distributions



Distributions are for offsets in cluster haloes

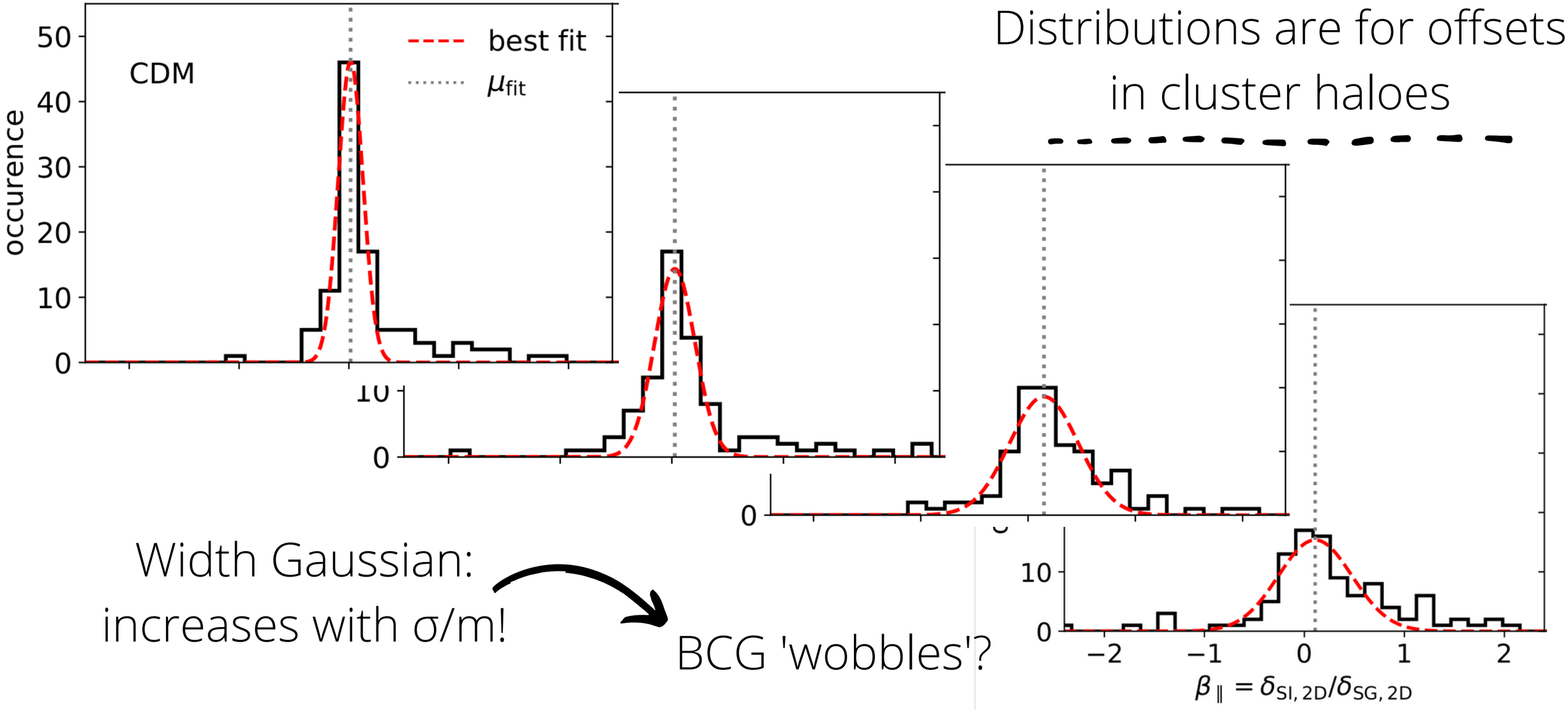
Widths of offset distributions

Distributions are for offsets in cluster haloes



Widths of offset distributions

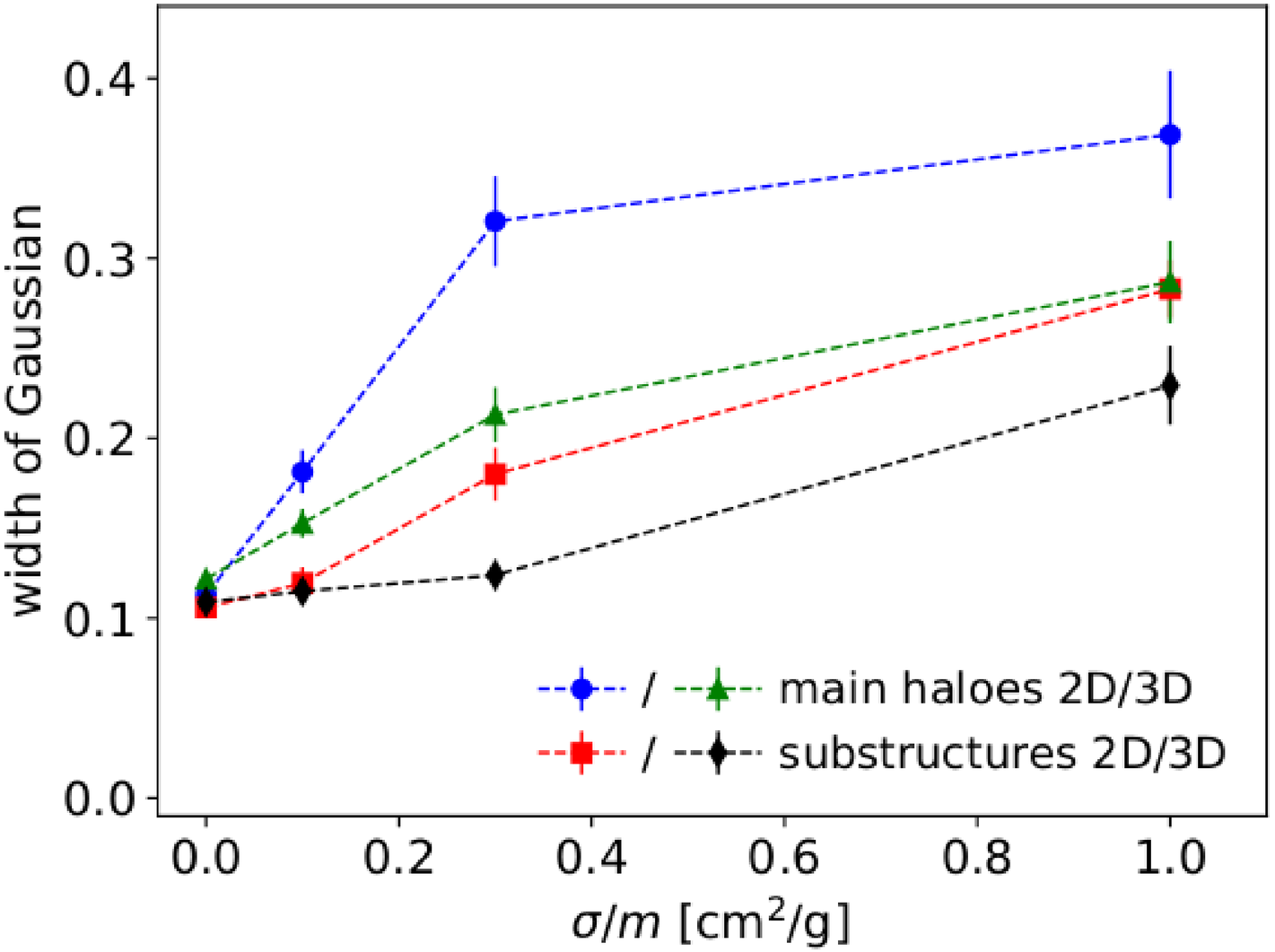
Distributions are for offsets in cluster haloes



Width Gaussian: increases with σ/m!

BCG 'wobbles'?

Widths of offset distributions



Effect stronger in cluster haloes

Effect stronger in 2D?

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Look at other projections?

Summary & next steps

Looked at DM-stellar offsets in merging clusters simulated with CDM & SIDM

- Offsets increase with cross-section, but CDM on average not zero
- Widths of offset distributions increase with cross-section: BCG wobbles?

Perform similar tests with observational techniques:

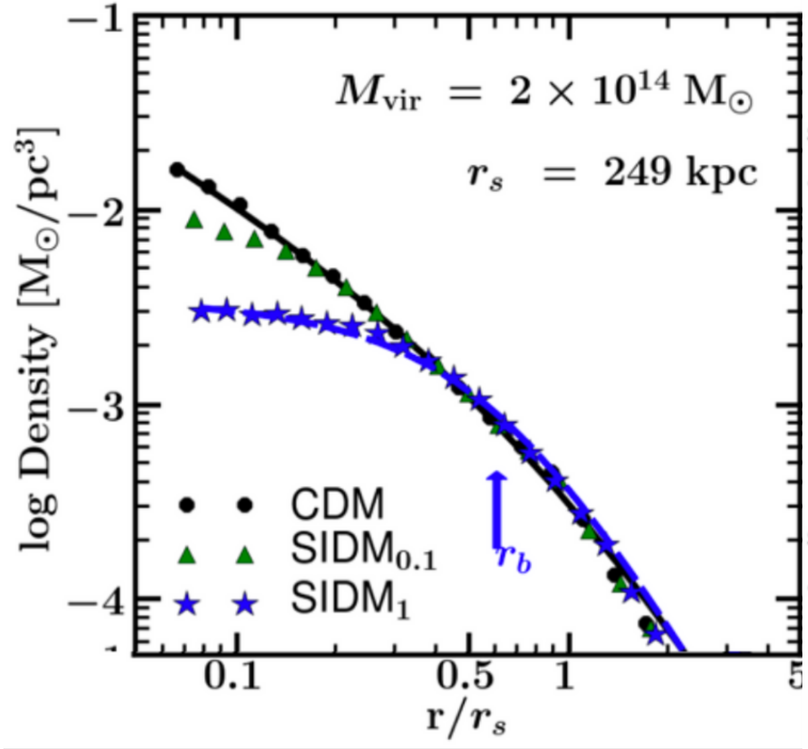
- Centre of DM with gravitational lensing
- Find stellar and x-ray peaks using peak-finders

Do full analysis on actual observational data?

Back-up

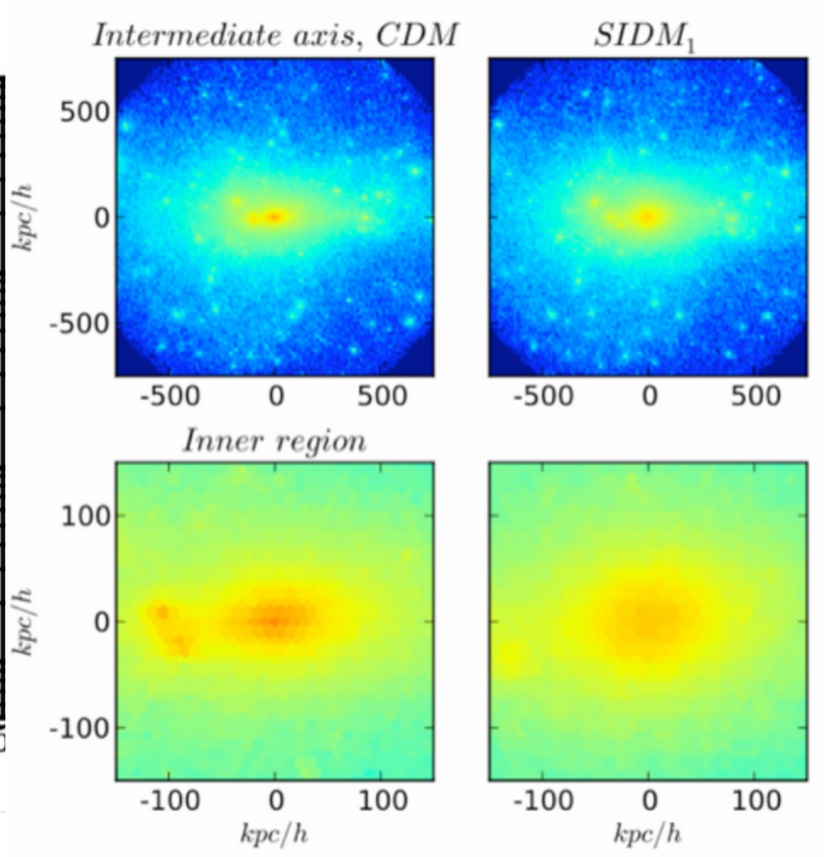
Current cluster constraints

Core sizes:
$\sigma/m < 1\ \mathrm{cm^2 g^{-1}}$



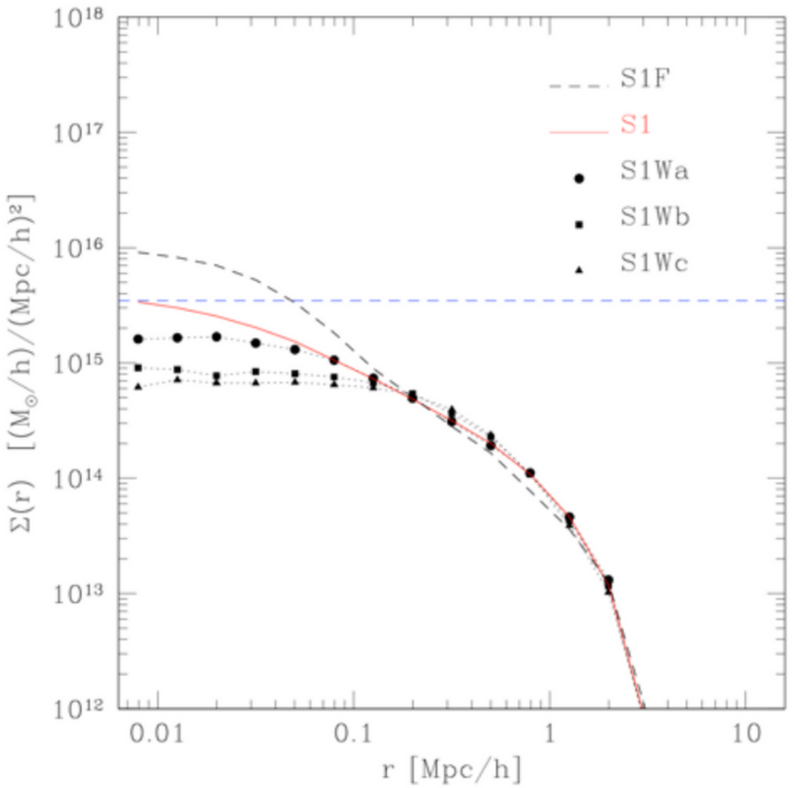
Rocha et al. 2012

Halo shapes:
$\sigma/m \lesssim 1\ \mathrm{cm^2 g^{-1}}$



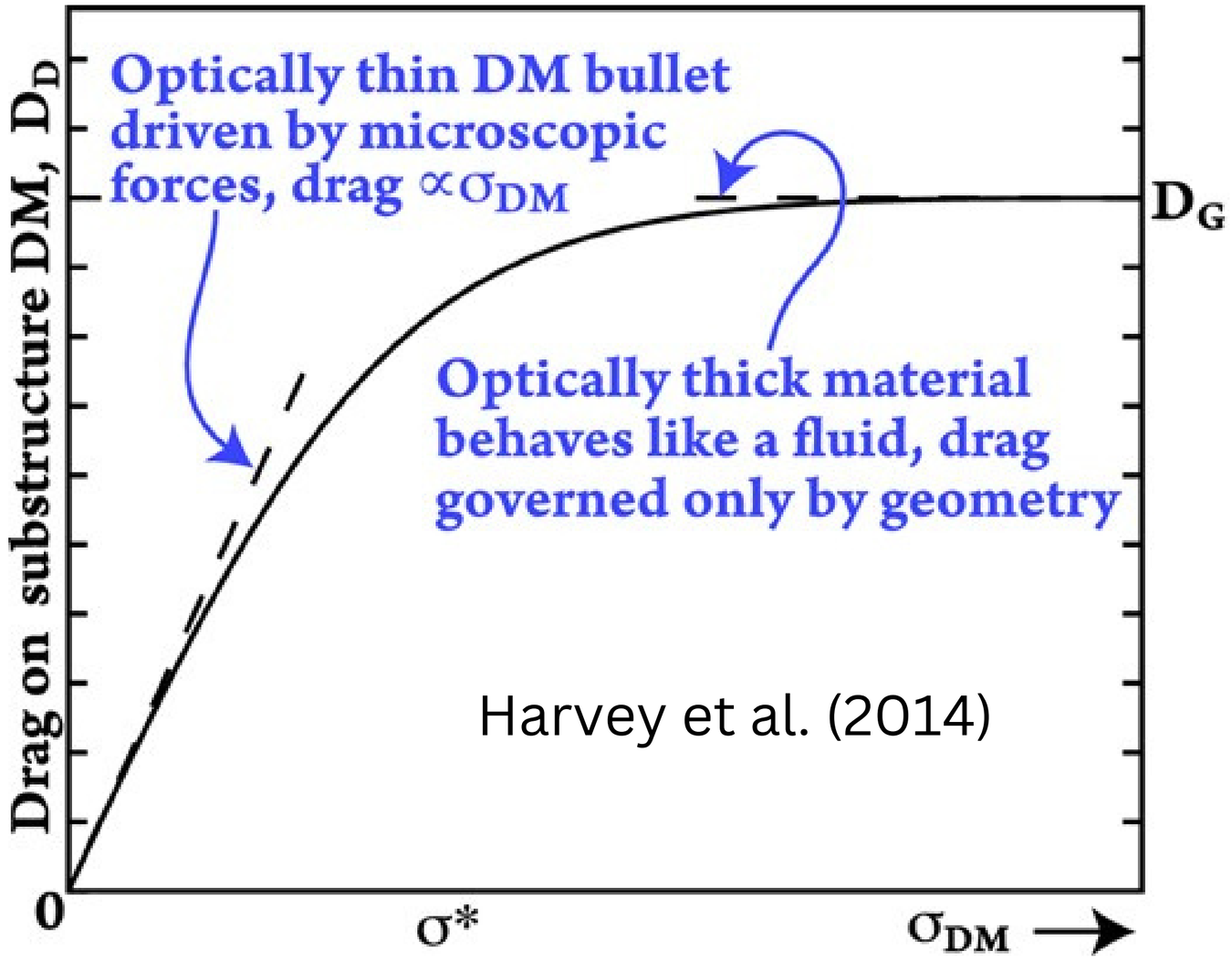
Peter et al. 2012

Strong lensing:
$\sigma/m < 0.1\ \mathrm{cm^2 g^{-1}}$



Meneghetti et al. 2000

Analytical model



Harvey et al. (2014)