The regeneration of dark matter cusps in CDM

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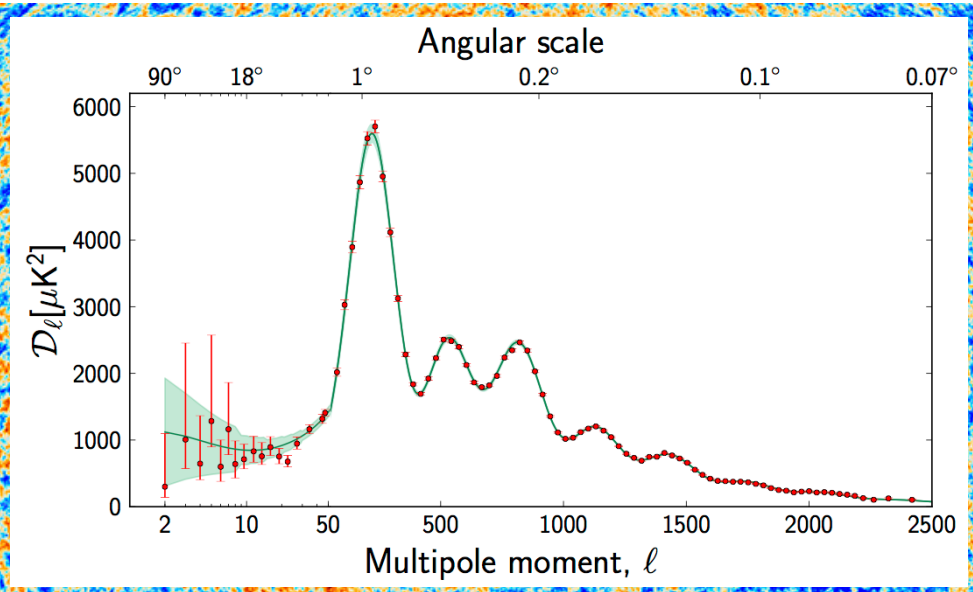
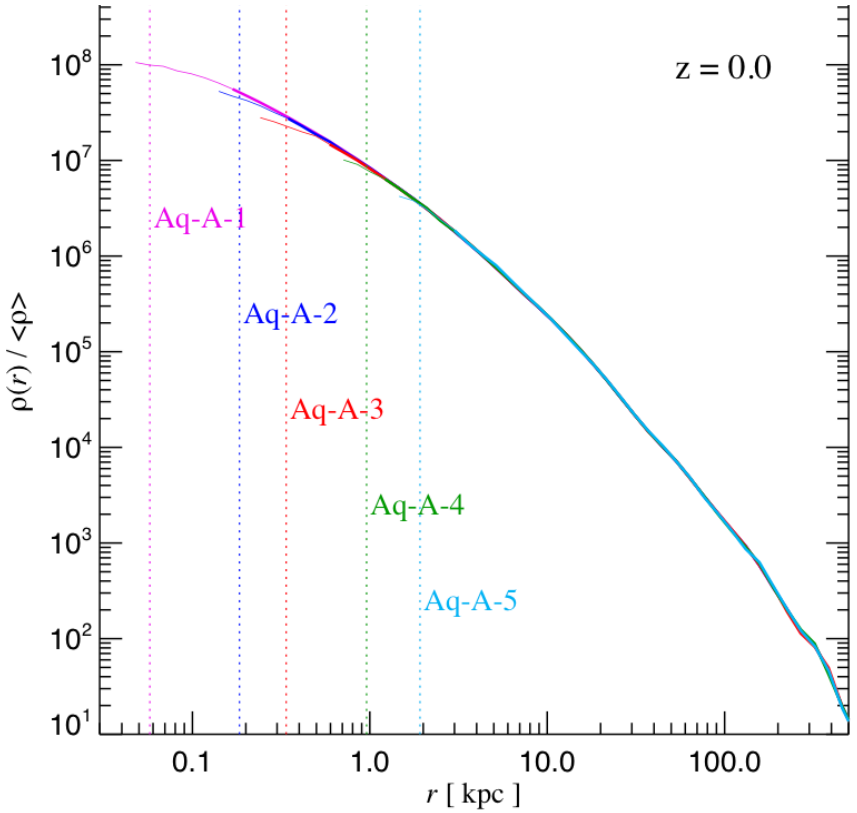
in collaboratoration with Jorge G. Penarrubia (RoE)

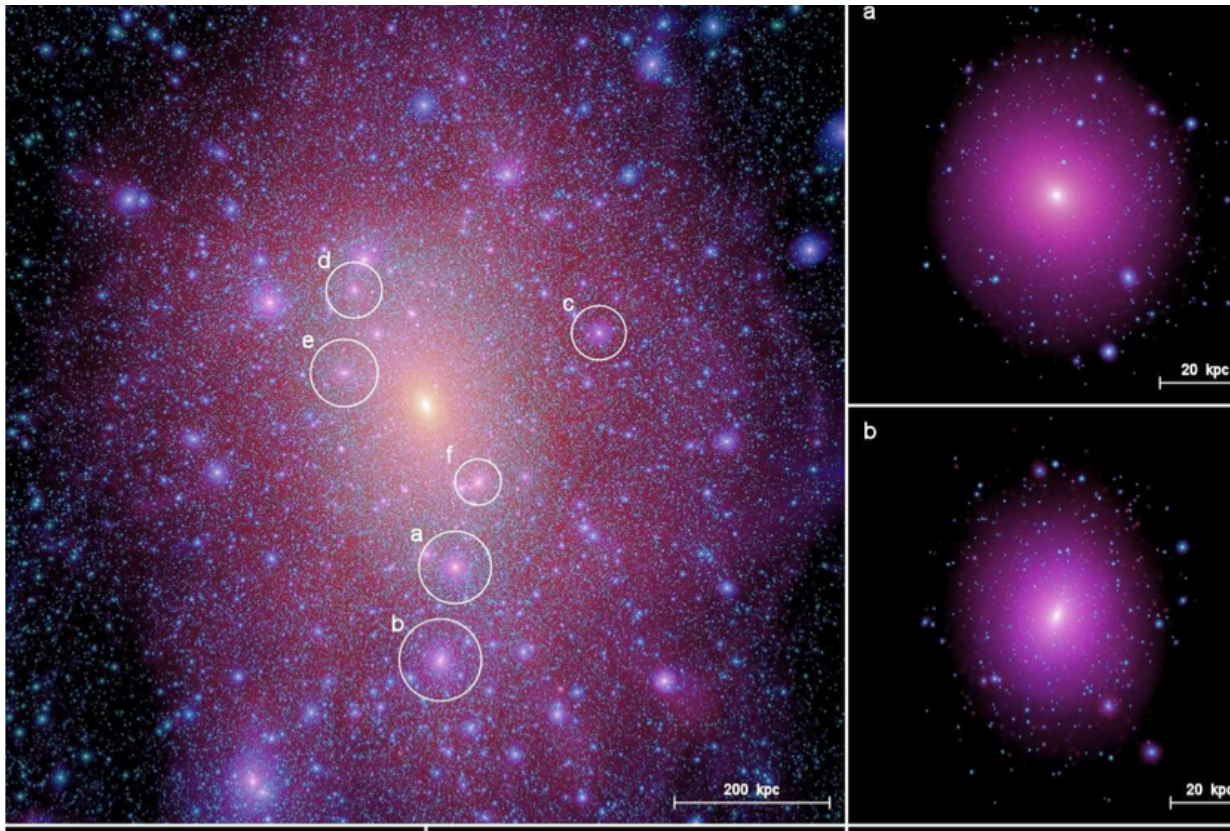
Streams and Satellites, Monday 13th April, Santiago, Chile

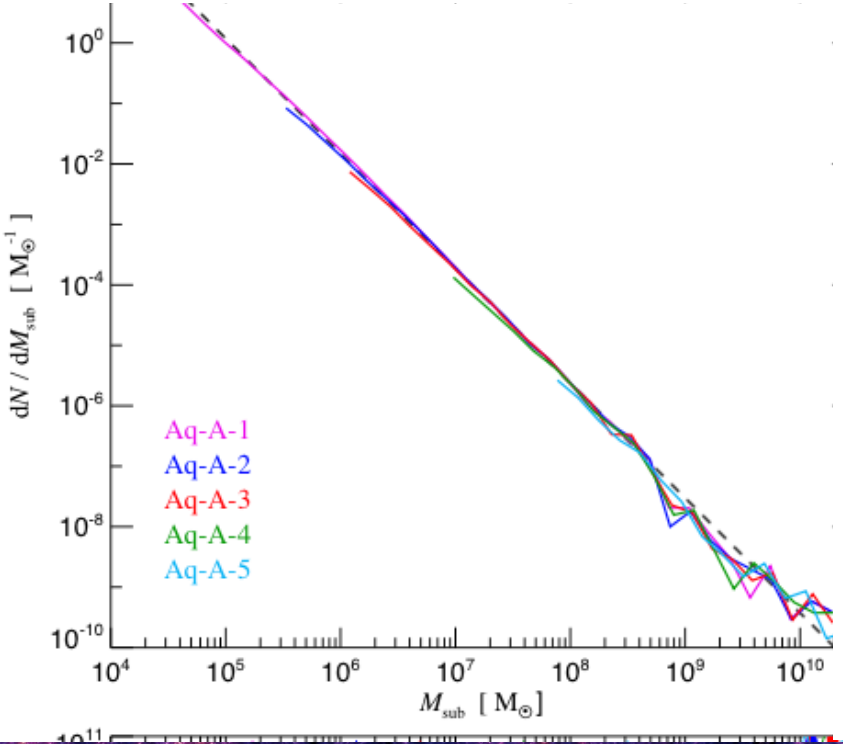


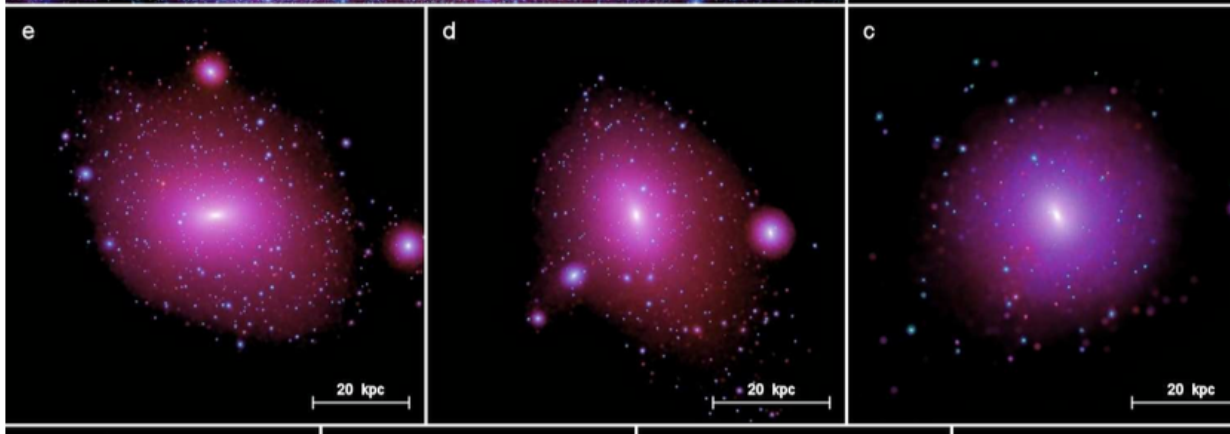
Given the initial conditions, N-body codes can simulate the evolution of the abundance, internal structure and clustering of dark matter halos to high-precision.

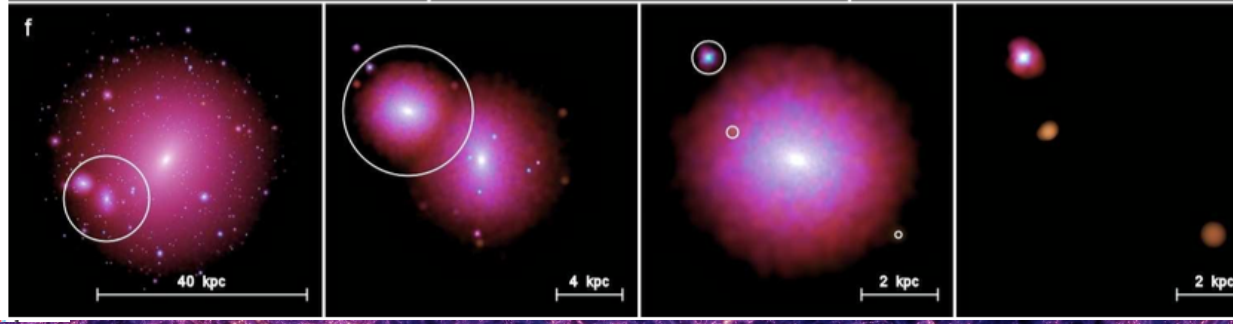
125 Mpc/h


z = 0.0
Aq-A-1
Aq-A-2
Aq-A-3
Aq-A-4
Aq-A-5
ρ(r) / <ρ>
r [kpc]


a
b
c
d
e
f
200 kpc
20 kpc

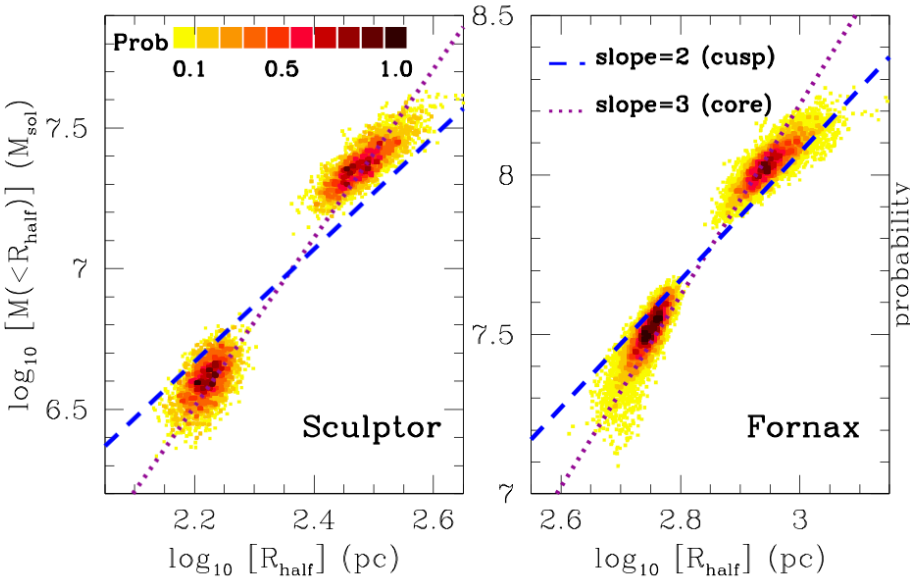

Aq-A-1
Aq-A-2
Aq-A-3
Aq-A-4
Aq-A-5
dN / dM_sub [M_⊙^-1]
M_sub [M_⊙]


e
d
c
20 kpc

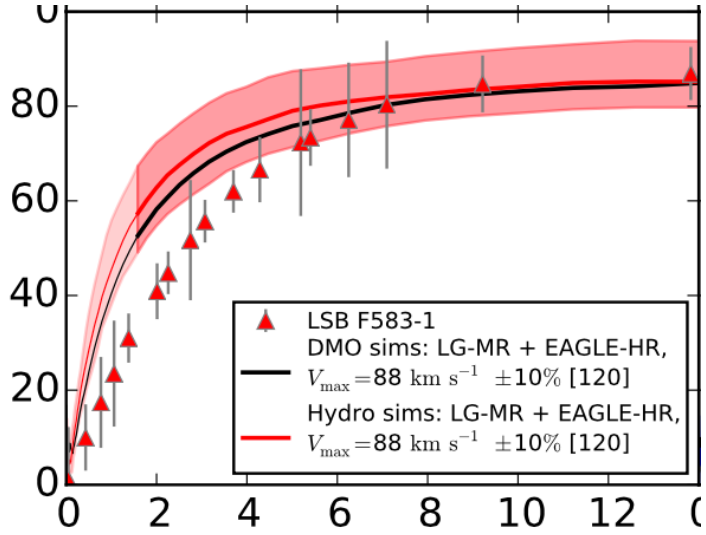

f
40 kpc
4 kpc
2 kpc
2 kpc

Cusp-core problem (which lead to

the re-invent the wheel problem(s))



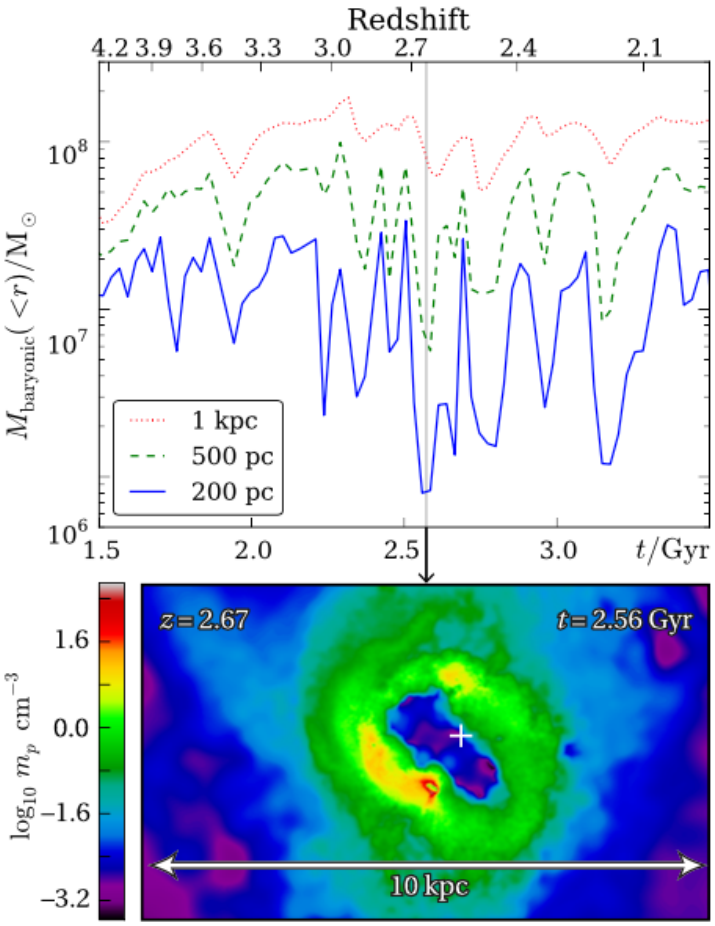
WP11



Oman+15

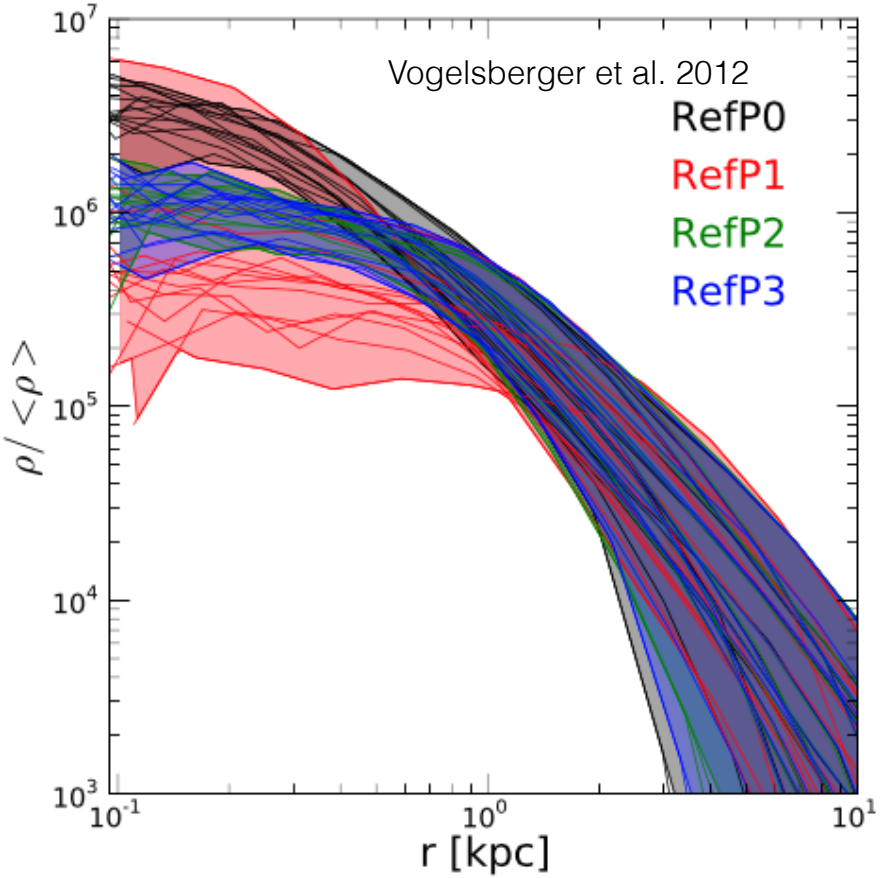
Proposed solutions to create cores

rapid potential changes ~O(1 Gyr)



Pontzen & Governato 12, see also Madau+14, Di Cintio+14, Onorbe+15

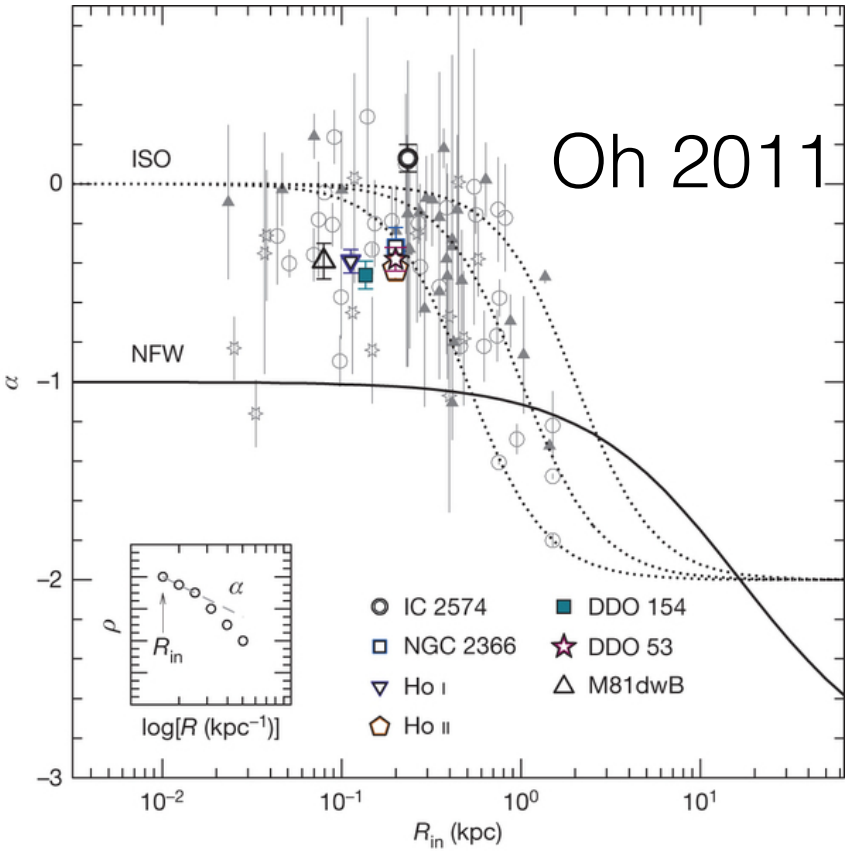
dark sector



see also Miguel-Rocha 2013, Vogelsberger et al. 2014

There is a scatter at a given mass scale

Diversity in LSBs



Does this depend on SFH?
e.g. Onorbe+15

Not really clear/supported
- in two slides :)

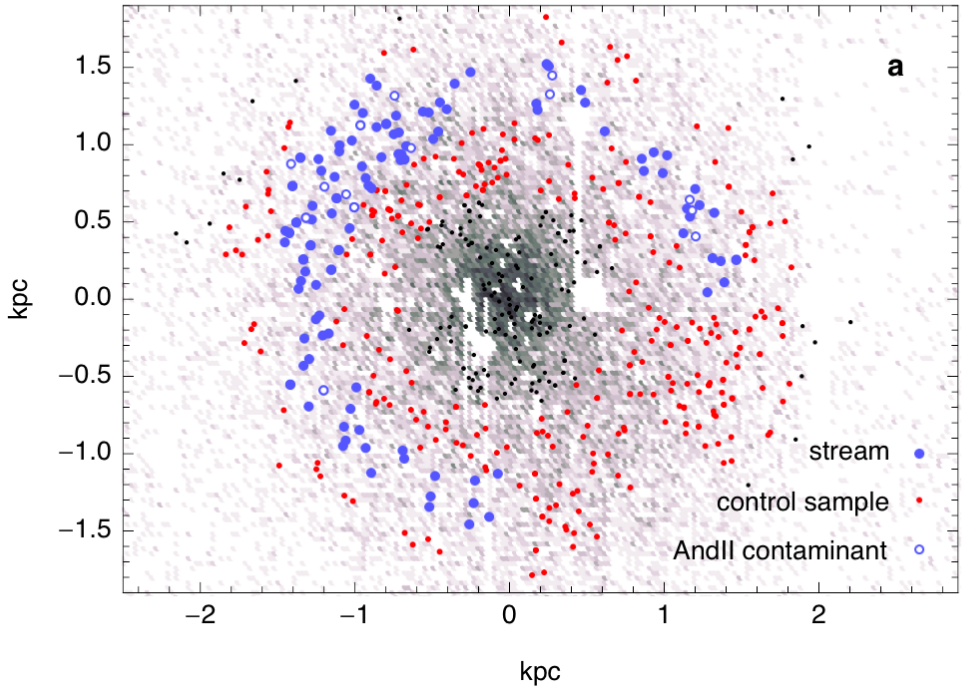
How long can cores survive in CDM?

- CDM predicts myriad of smaller substructure, some which should be completely dark.
- Assembly history of dwarf galaxies poorly studied - only few simulations available to address this in detail.
- We do observe galaxies merging with darker companions…

Dwarf-dwarf mergers

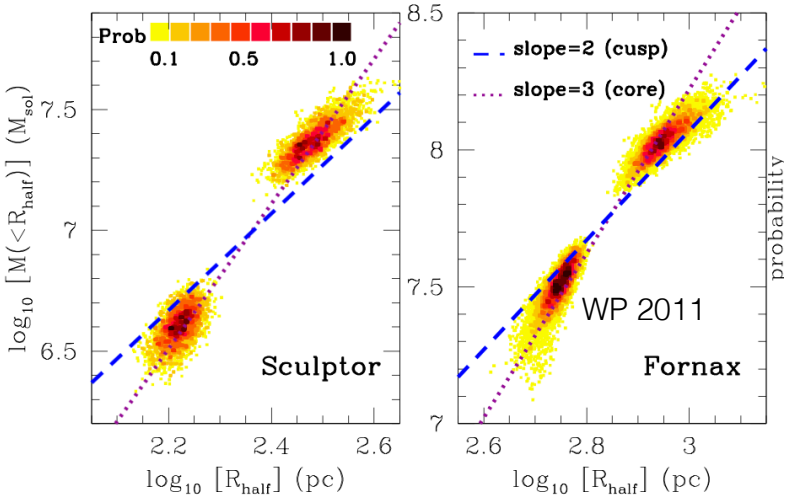
Image: R. Jay GaBany (Blackbird Observatory) in collaboration with David Martinez-Delgado (MPIA). Inset image: R. Jay GaBany (Blackbird Observatory), Aaron Romanowsky (UCSC) and Jacob Arnold (UCSC) in collaboration with David Martinez-Delgado (MPIA) and the National Astronomical Observatory of Japan (NAOJ)

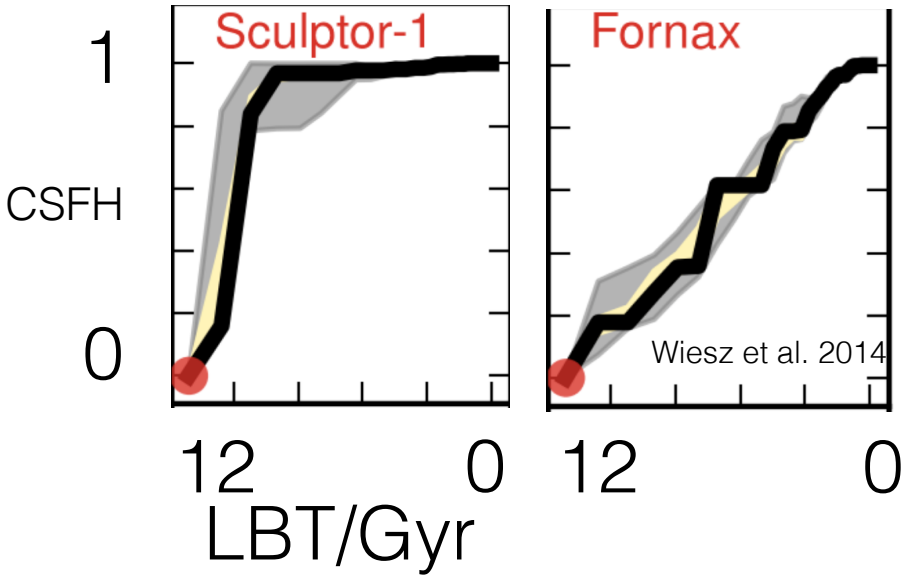
dwarf-“almost dark” satellite merger: And II



Amorisco et al. 2014

What does nature tell us?





different SFH
hint towards high-z cusp-core transformation

- Use merger trees of dwarf galaxies in the Aquarius simulations (Aq-A-2: mp=1e4Msun, epsilon=100 pc).

- Select potential candidates with close pericentric passages for re-simulation.

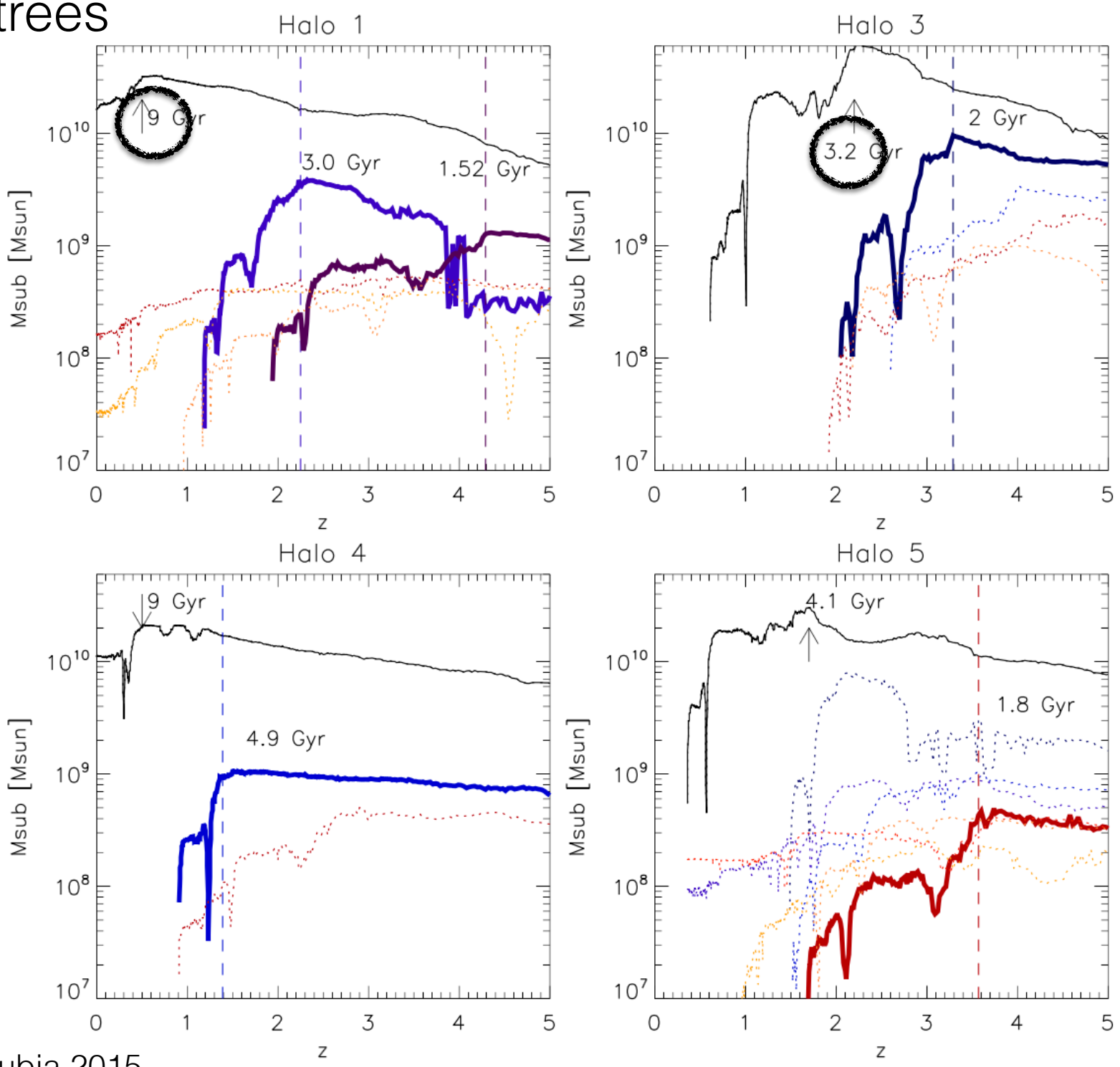
- Assume core transformation occurs at high-z as suggested by analytical / hydrodynamical simulations.

Dwarf merger trees

infall z onto host MW

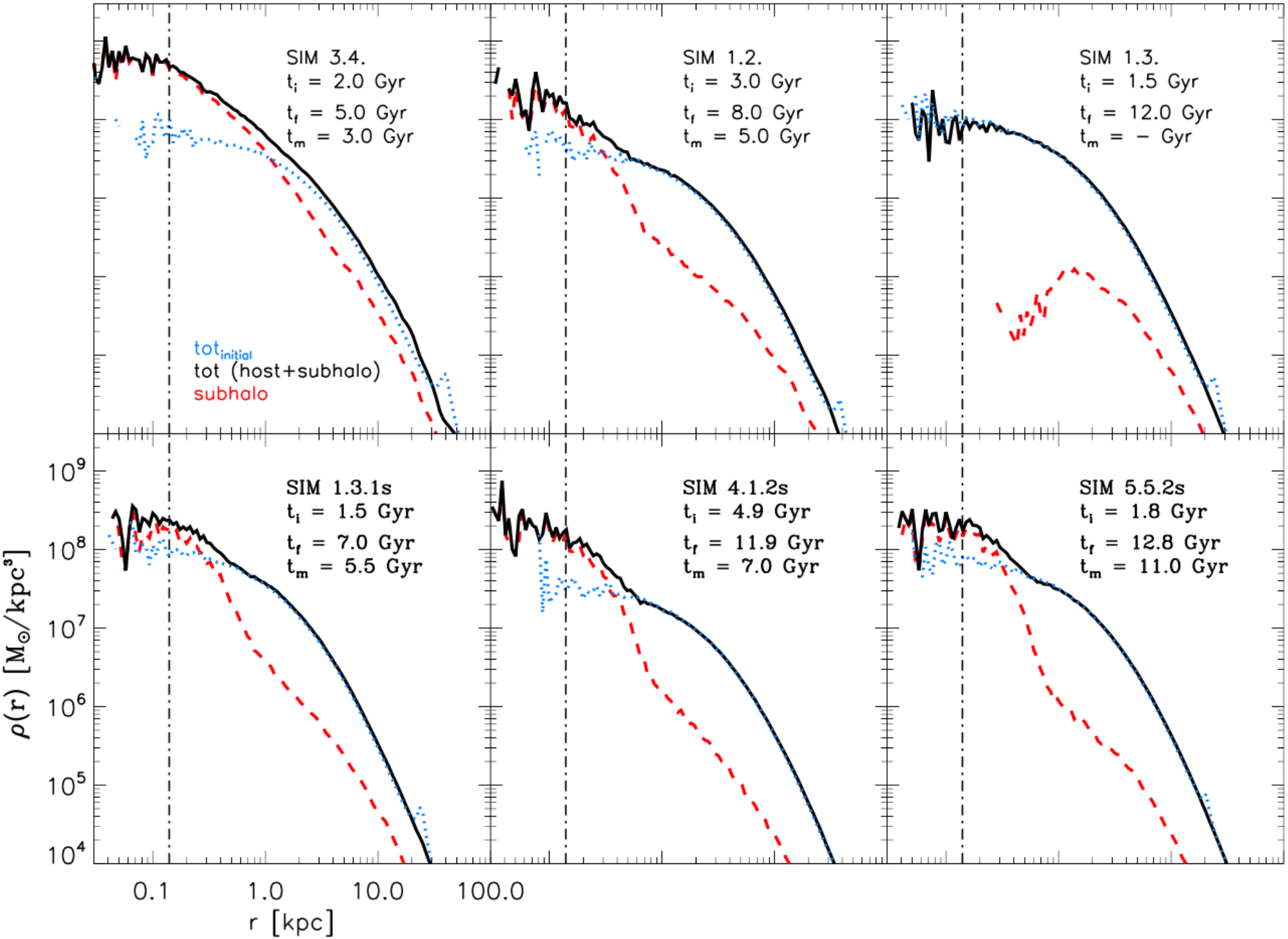
infall z onto dwarf halo

peri= lt 10 kpc

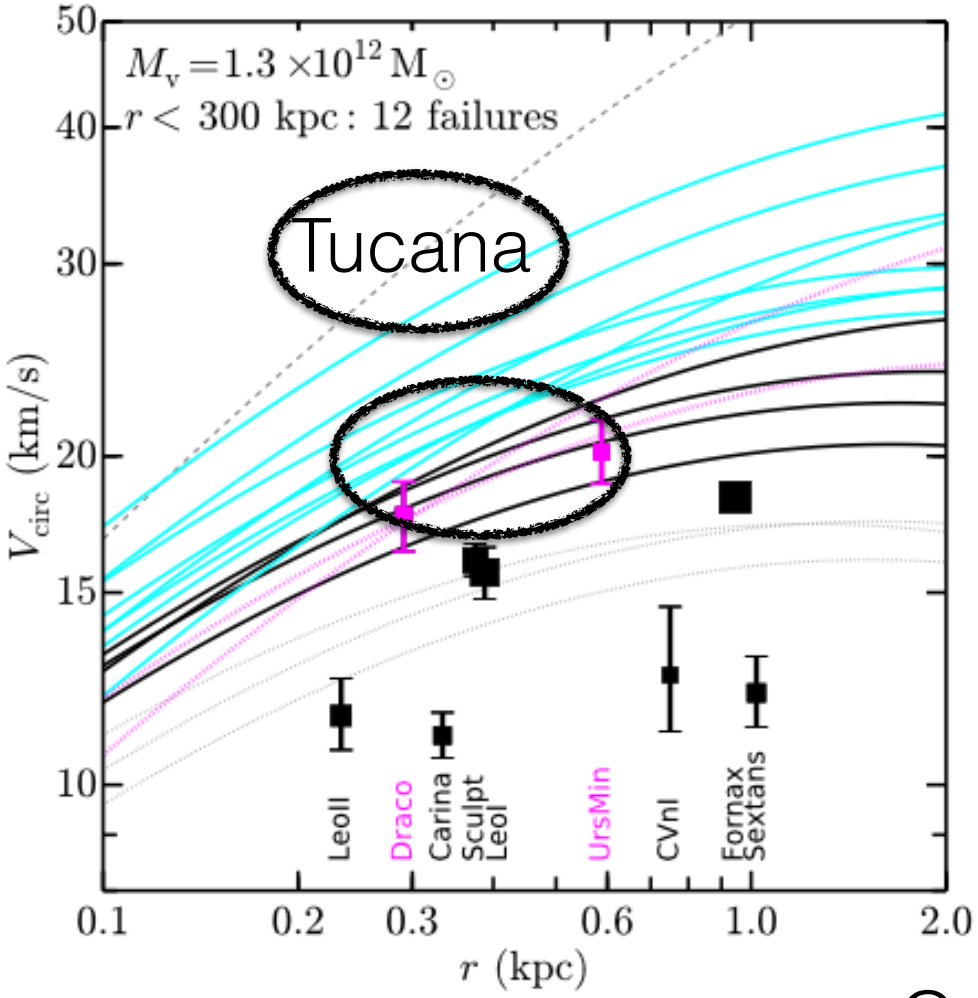


Laporte & Penarrubia 2015

Run	q	r_c kpc	a_s kpc	δ_ρ	$r_{a/p}$	r_a kpc	t_s Gyrs
3.4.	1:3	5.1	6.2	0.18	14	44	2.0
1.2.	1:6	5.0	5.2	0.12	4.0	40	5.0
1.2.1s	1:6	5.0	4.0	0.22	4.0	40	4.6
1.2.2s	1:6	5.0	3.2	0.38	4.0	40	4.3
1.2.3s	1:6	5.0	2.6	0.63	4.0	40	4.3-8.0
1.3.	1:8	3.0	3.2	0.11	3.0	27	-
1.3.1s	1:8	3.0	2.4	0.21	3.0	27	5.0
1.3.2s	1:8	3.0	2.0	0.31	3.0	27	4.6-8.0
1.3.3s	1:8	3.0	1.6	0.54	3.0	27	4.4-7.0
4.1.	1:20	5.0	3.2	0.18	18	45	-
4.1.1s	1:20	5.0	2.6	0.28	18	45	-
4.1.2s	1:20	5.0	2.1	0.45	18	45	7
4.1.3s	1:20	5.0	1.6	0.92	18	45	6.5
5.5.	1:30	3.7	2.3	0.12	5	22	-
5.5.1s	1:30	3.7	1.8	0.22	5	22	-
5.5.2s	1:30	3.7	1.4	0.41	5	22	5.0-11.0
5.5.3s	1:30	3.7	1.2	0.54	5	22	4.0-10.0


SIM 3.4.
t_i = 2.0 Gyr
t_f = 5.0 Gyr
t_m = 3.0 Gyr
SIM 1.2.
t_i = 3.0 Gyr
t_f = 8.0 Gyr
t_m = 5.0 Gyr
SIM 1.3.
t_i = 1.5 Gyr
t_f = 12.0 Gyr
t_m = – Gyr
SIM 1.3.1s
t_i = 1.5 Gyr
t_f = 7.0 Gyr
t_m = 5.5 Gyr
SIM 4.1.2s
t_i = 4.9 Gyr
t_f = 11.9 Gyr
t_m = 7.0 Gyr
SIM 5.5.2s
t_i = 1.8 Gyr
t_f = 12.8 Gyr
t_m = 11.0 Gyr
$tot_{initial}$
tot (host+subhalo)
subhalo
$\rho(r)$ [$M_\odot$/kpc^3]
10^9
10^8
10^7
10^6
10^5
10^4
0.1
1.0
10.0
100.0
r [kpc]

Dense dSphs

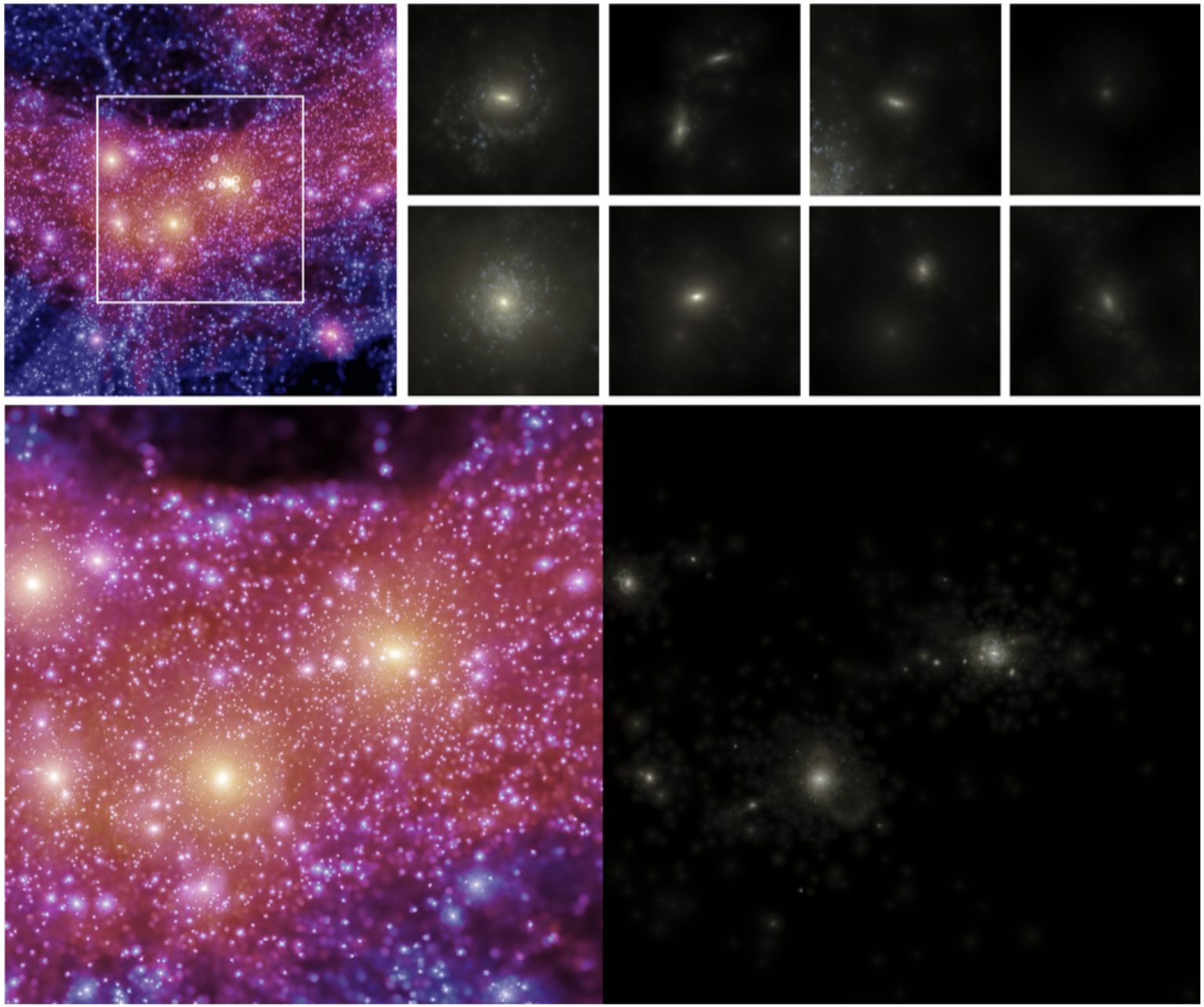


Garisson-Kimmel+14

Future outlook

- Theoretical: Study the process in a full cosmological context to get statistics of occurences of mergers with dark substructure: -> inner mass profiles + consequences for stellar light and transformation to dwarf spheroidal (Helmi+13, Starkenburg & Helmi14)

- Observational: push measurements to faint dwarfs (not very creative but there is potential to characterise this: induced rotation on the stellar remnant (And II), Carina has two stellar populations, Ursa Minor. Cusp regrowth should not correlate with SFH, while persistent cusp should correlate with SFH.

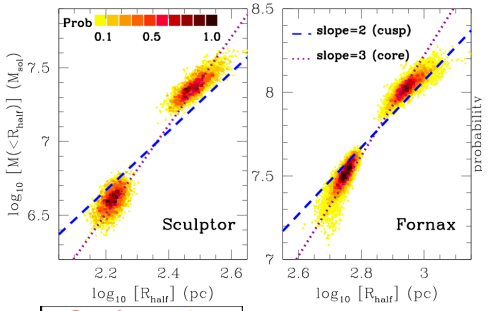


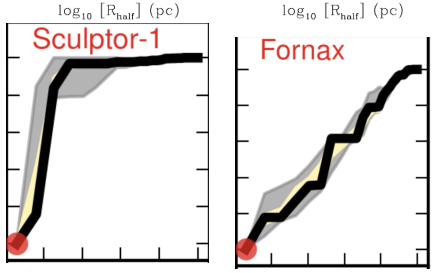
sawala+14

Laporte, Sawala, Oman, Navarro, Frank (in early-prep still)

The future

WP 2011





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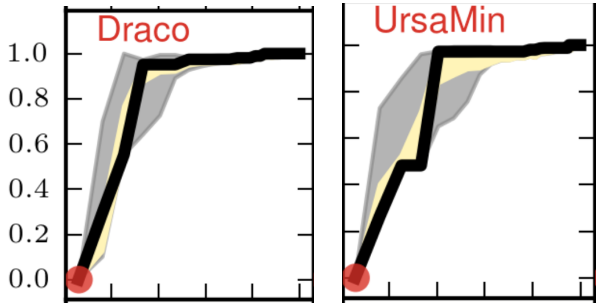

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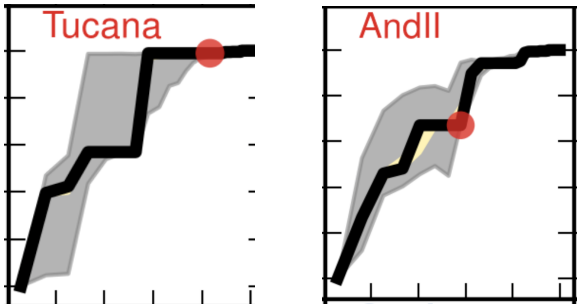
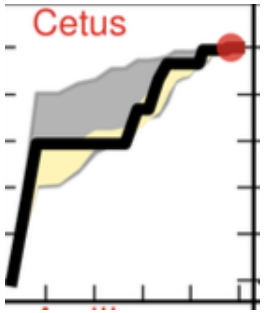


Wiesz et al. 2014



far

Conclusions

- Cusp regrowth can occur in CDM from LSBs down to dSph systems.
- Together with baryonic physics, CDM gives rise to a large phenomenology if proved to occur can be used to rule out some alternative DM models (e.g. WDM or some (not all) SIDM models).
- There is no cusp-core problem, there is a diversity problem at a fixed mass scale which needs to be addressed on the scale of LSB and possibly dSph scales.