The Impact of Baryonic Physics on the Structure of Dark Matter Halos

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UCSC galaxy workshop

Background

- Some problems on CDM paradigm:
  1. core/cusp
  2. Too Big To Fail
  3. halo expansion instead of baryonic contraction
- Solutions:
  1. warm dark matter
  2. self-interacting dark matter
  3. stellar feedback **(our topic today)**

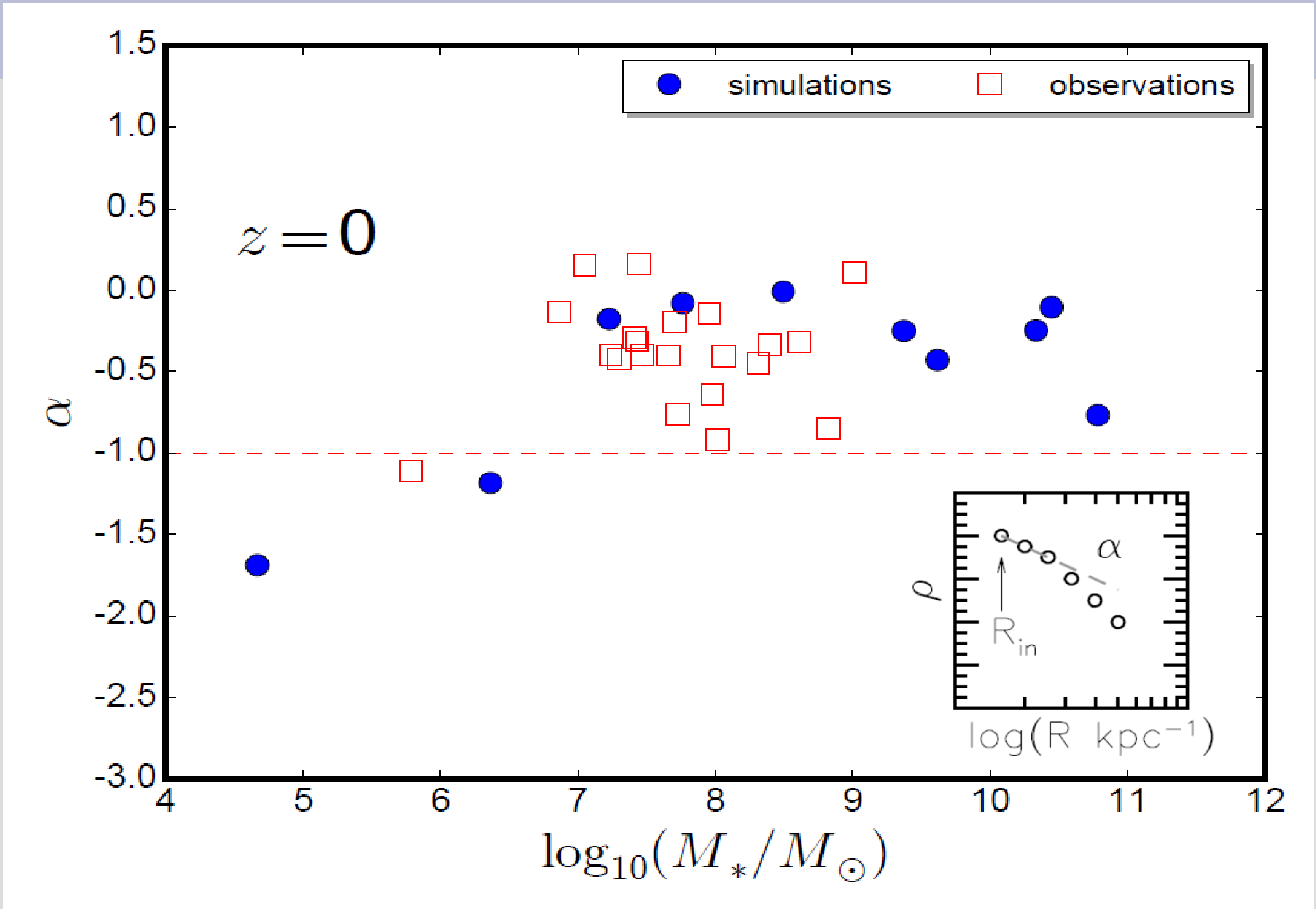
Simulations (FIRE)

1. cooling, star formation and stellar feedback,
2. high resolution,
3. isolated galaxies, from dwarfs to MW-mass galaxies

	$M_{halo}(M_{sun})$	$M_{star}(M_{sun})$	$m_{dm}(M_{sun})$	$\varepsilon_{dm}(pc)$
m09	2.6e9	4.6e4	1.3e3	29
m10	7.9e9	2.3e6	1.3e3	29
m10h1297	1.3e10	1.7e7	7.3e3	43
m10h1146	1.6e10	7.9e7	7.3e3	43
m10h573	4.0e10	3.2e8	5.9e4	1.0e2
m11	1.4e11	2.4e9	3.5e4	71
m11h383	1.6e11	4.0e9	5.9e4	1.0e2
m12v	6.3e11	2.9e10	2.0e5	2.9e2
m12i	1.1e12	6.1e10	2.8e5	1.4e2
m12q	1.2e12	2.1e10	2.8e5	2.1e2

Core/Cusp

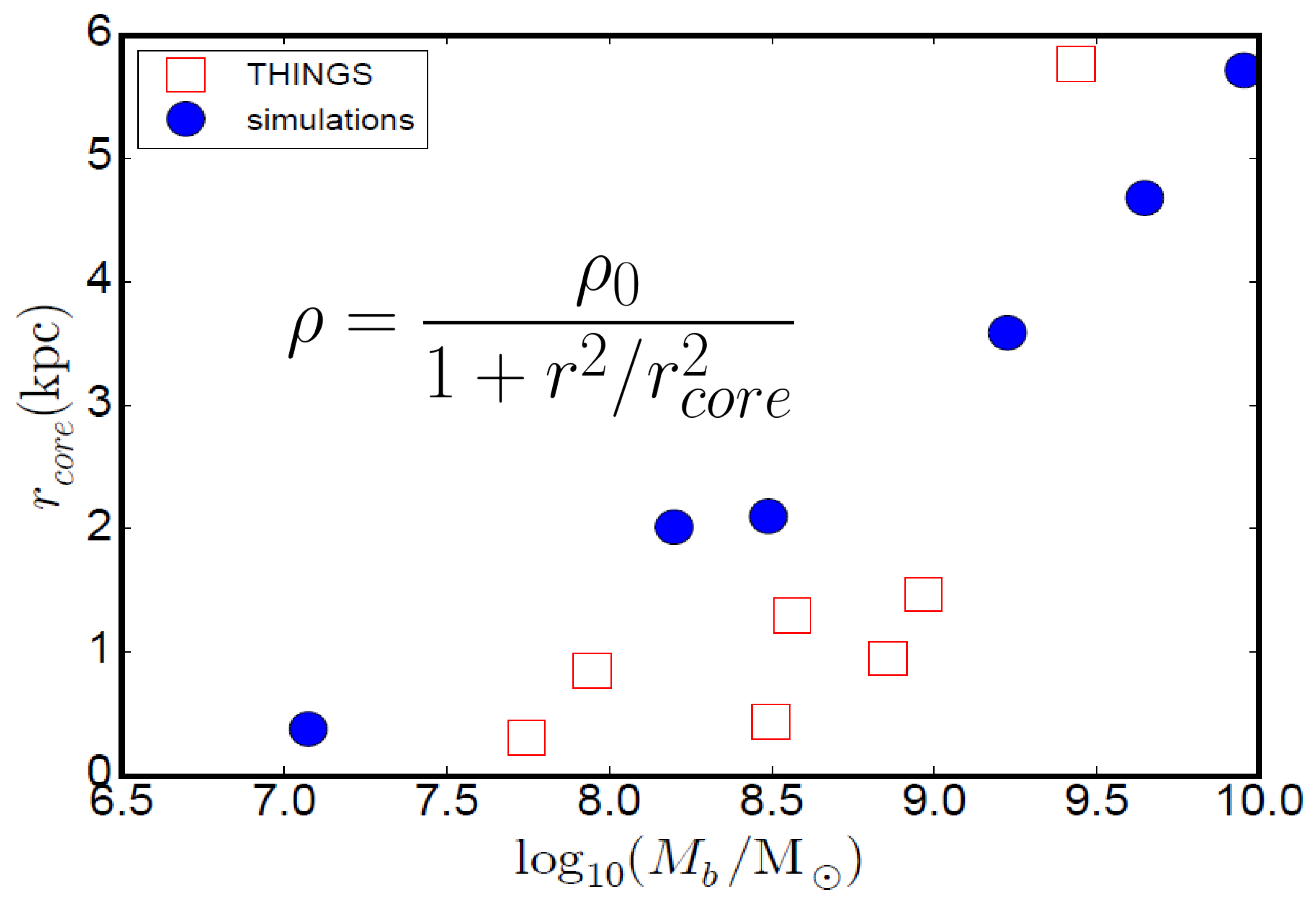
(alpha measured between 300-700 pc)



Oh et al. 2011

Feedback flattens DM profiles, especially $M_{star} \sim 10^{7\text{-}9}\ M_{sun}$

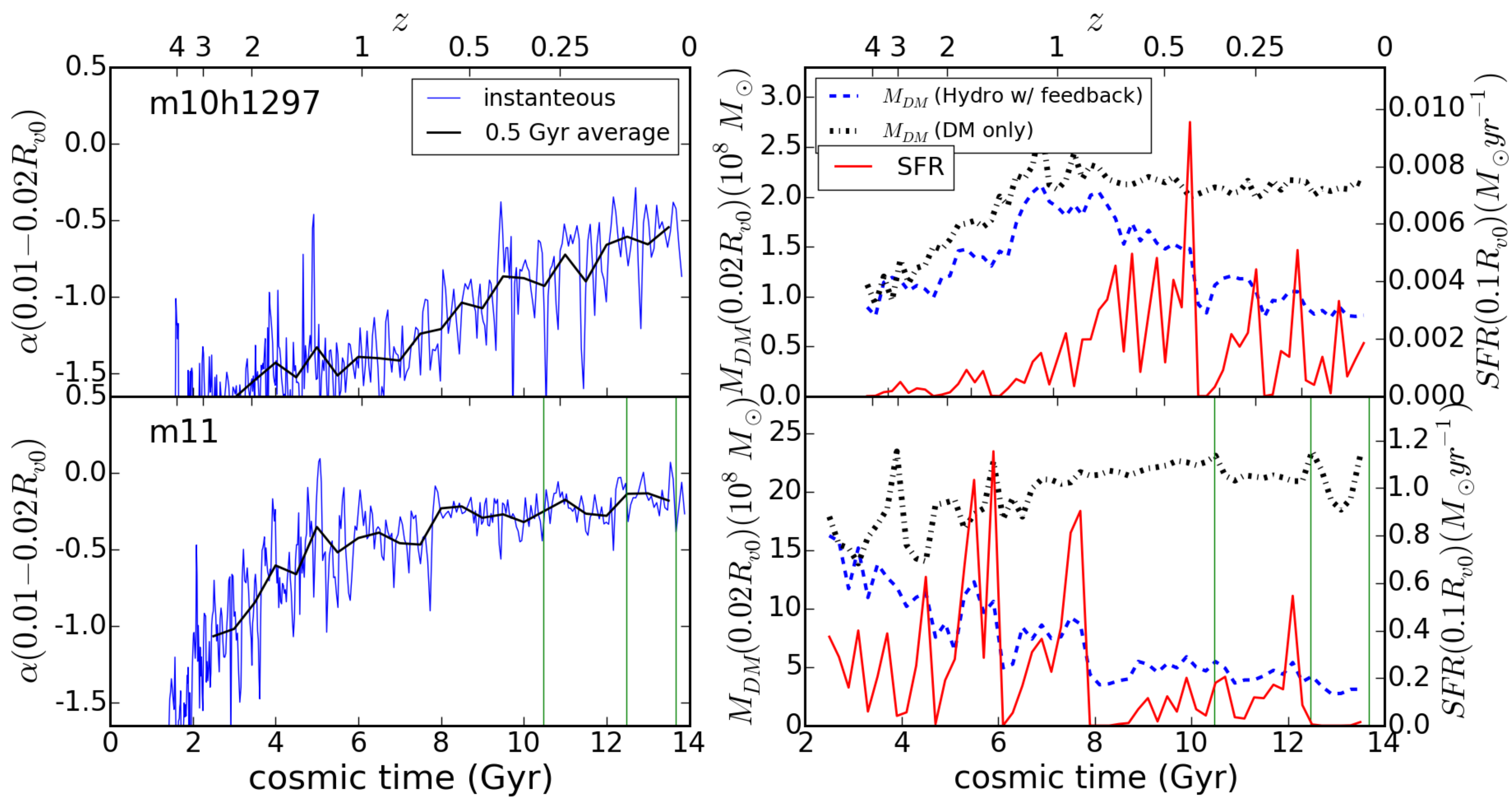
Core/Cusp (2)



Oh et al. 2011

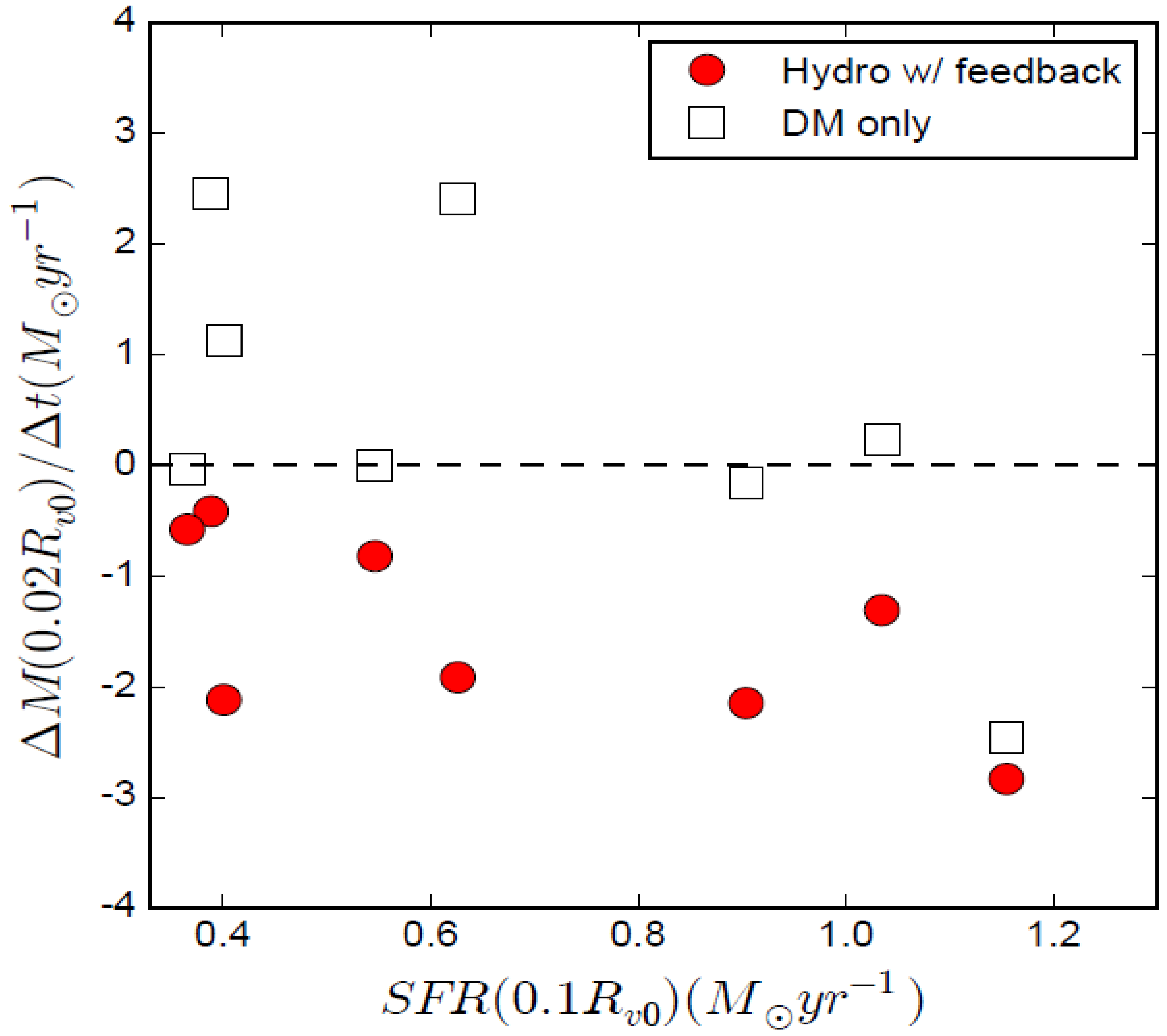
Baryons have little effects on DM at $M_{baryon}<10^{7.5}M_{sun}$ or $M_{star}<10^{7}M_{sun}$

The evolutions of DM slope, enclosed DM mass and SFR



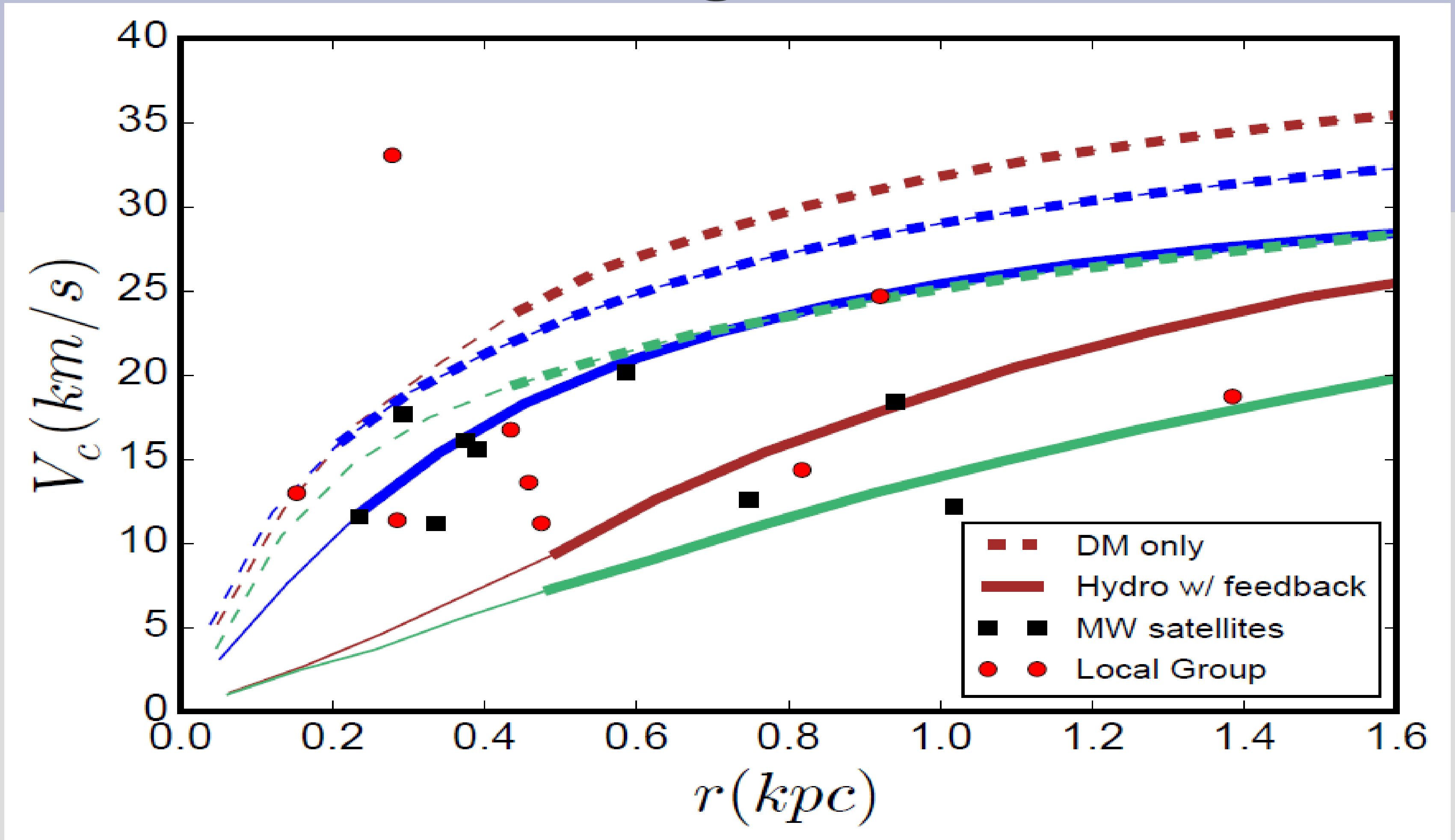
Stellar feedback starts forming cores at early times but the cores are established typically at later times (also Onorbe et al 2015).

The correlation between SFR and DM outflow in m11



- Change in enclosed DM mass between t and t+0.2Gyr
- Star Formation Rate between t-0.2Gyr and t
- Eight largest peaks of SFR
- The enclosed DM mass is reduced after strong bursts of star formation.

Too Big To Fail



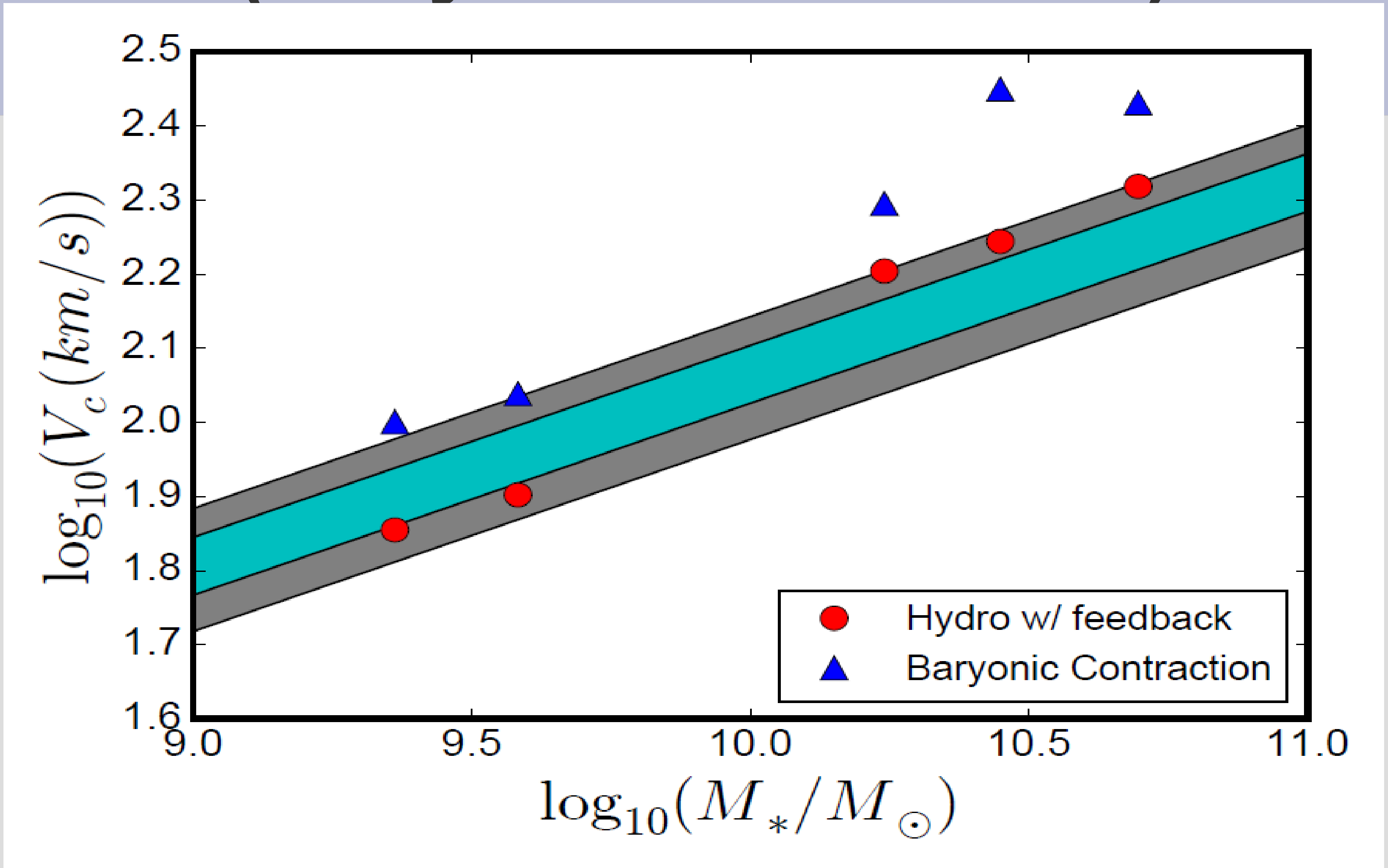
Ref: Strigari, Kaplinghat & Bullock 2007; Walker et al. 2009; Wolf et al. 2010; Kirbyet al. 2014,

m10 (M_{star} = 2.3 x10^6M; blue)
m10h1297 (M_{star} = 1.7 x 10^7M; green)
m10h1146 (M_{star} = 7.9 x 10^7M; brown)

TBTF mass range:
M_{star}~5x10^5-5x$10^7$$M_{sun}$

Feedback reduces central density and alleivates TBTF.

Halo expansion (Tully-Fisher relation)



- Circular velocities measured at half stellar mass radius.
- the best fit of the observed TFR in Dutton et al. 2007
- Stellar feedback helps to establish the observed Tully- Fisher relation.

Conclusion

1. The baryons have little influence on halos with M_{halo}~ $10^{10}M_{sun}$, which is perfect places for testing various theories of dark matter.

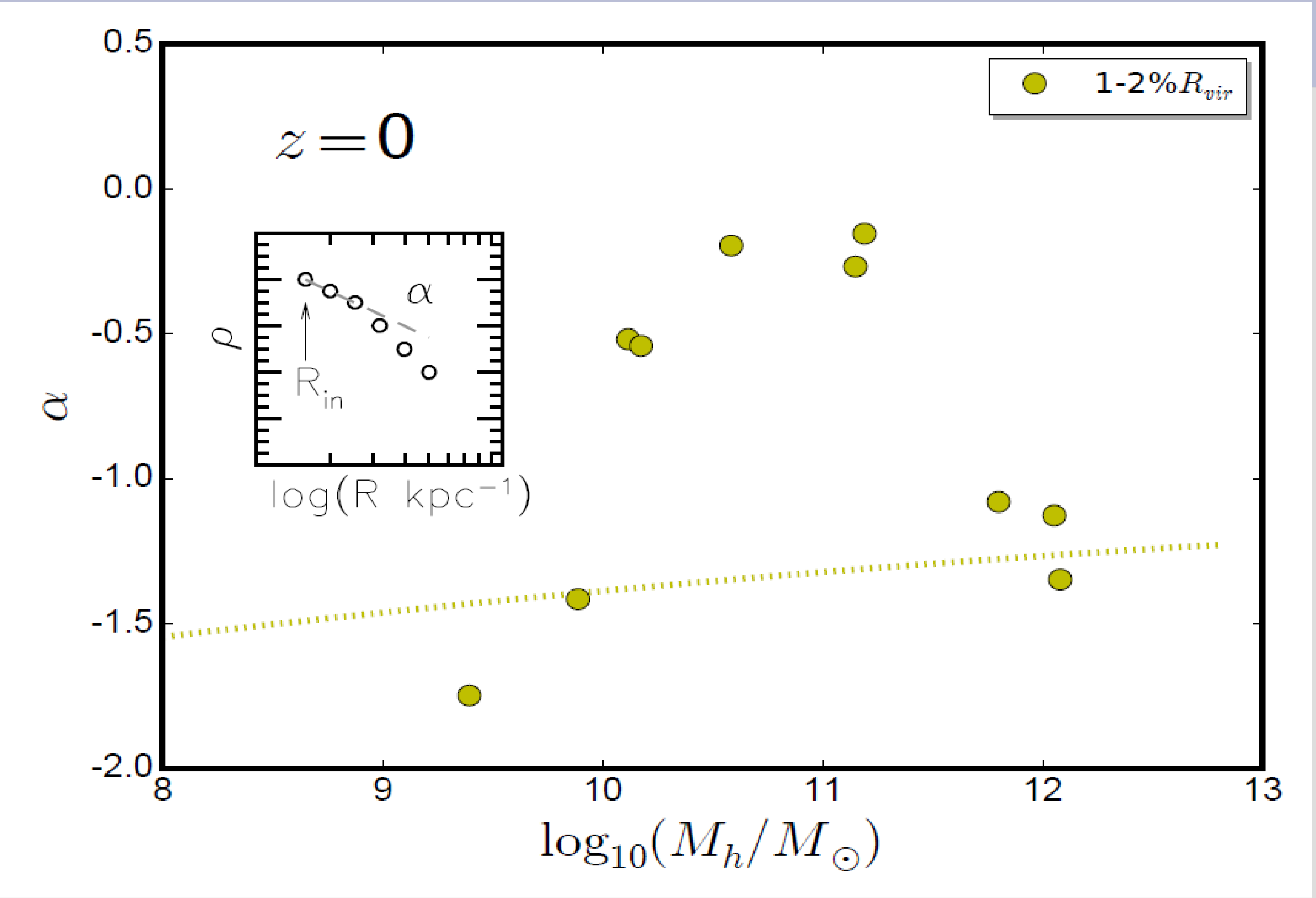
2.The central slopes of dark matter density profiles are governed by halo mass and stellar mass. Profiles are shallow with relatively large cores for $M_{halo} \sim 10^{10\text{-}11}M_{sun}$ / $M_{star} \sim 10^{7\text{-}9} M_{sun.}$

3.Bursts of star formation and feedback start forming cores at early times but the cores are established typically at later times.

4. Stellar feedback in galaxies with $M_{star} \sim 10^{6\text{-}8} M_{sun}$ lowers the central density of dark matter halos and substantially alleviates the “To Big To Fail” problem.

5. Stellar feedback, which counteracts the effects of adiabatic contraction, appears necessary to establish the observed normalization of the Tully-Fisher relation.

Core/cusp
(Dark matter inner density slope)



Feedback flattens DM profiles, especially $M_{halo} \sim 10^{10\text{-}11}\ M_{sun}$