Semi-analytical modeling of dwarf galaxies in a ΛCDM framework

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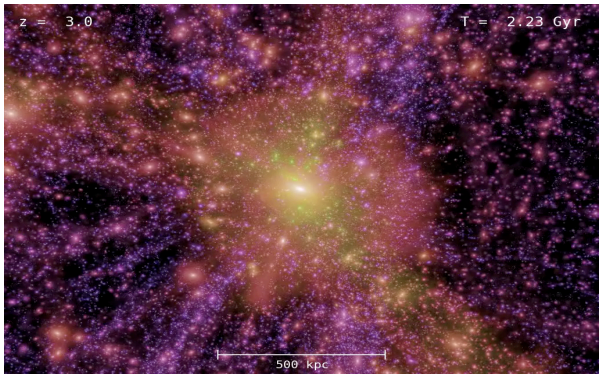
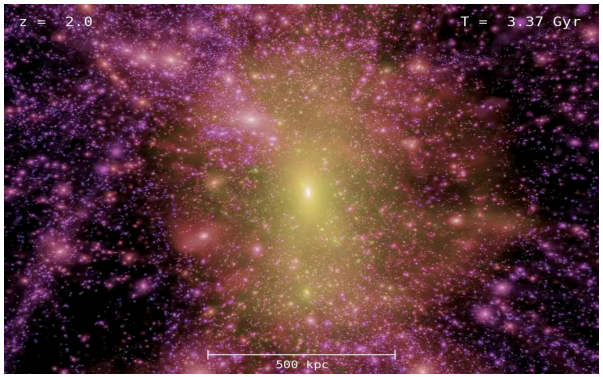
Outline

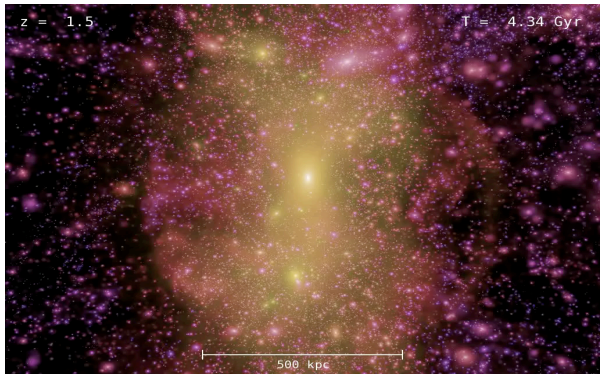
- Introduction
  - Semi-analytical modeling
  - Our model
- A few examples
  - What is missing: the mass of the Milky Way
  - The shape of the galaxy mass – halo mass relation
  - Satellites' orbits

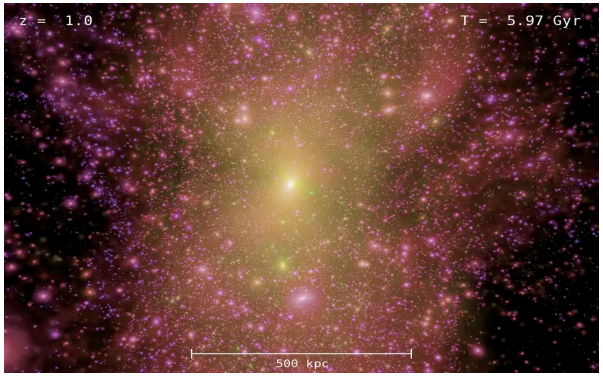
Semi-analytic models of the Milky Way

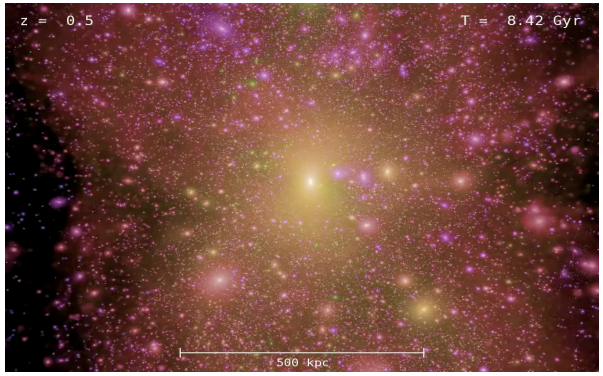
How to get from here







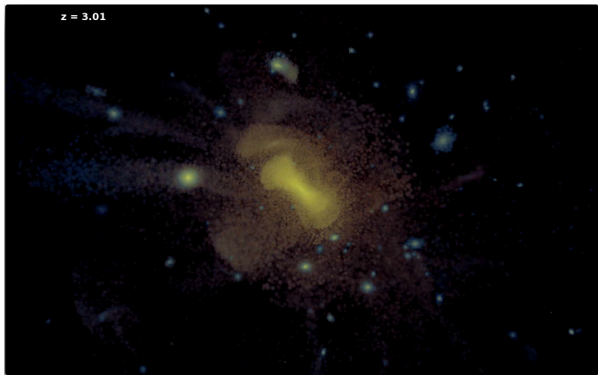


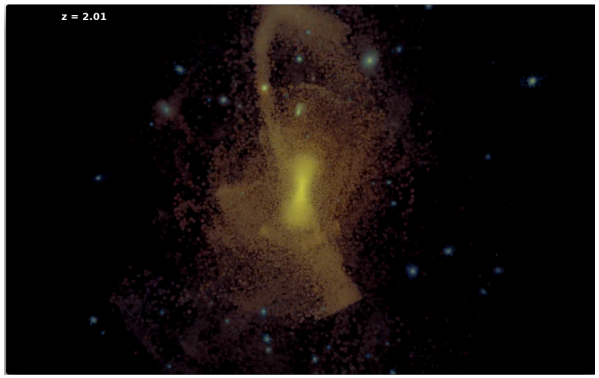


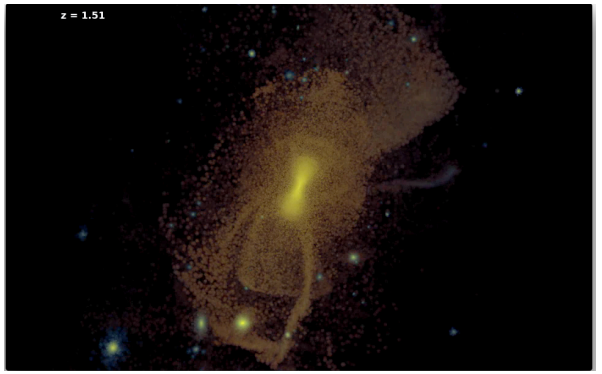
Credit: J. Helly, A. Cooper, S. Cole and C. Frenk (ICC), based on simulation data from The Virgo consortium and software by V. Springel

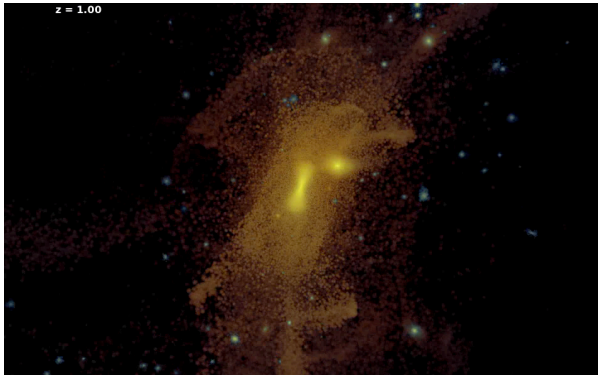
Semi-analytic models of the Milky Way

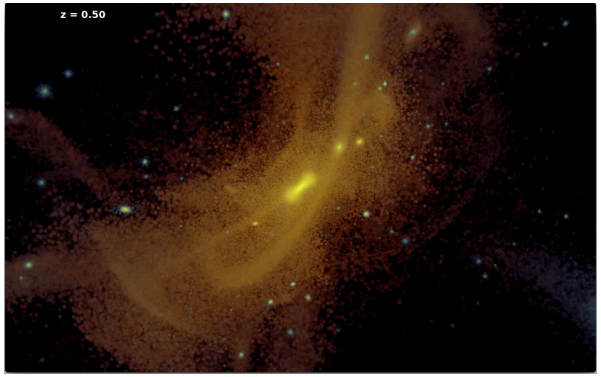
How to get from here …. to here

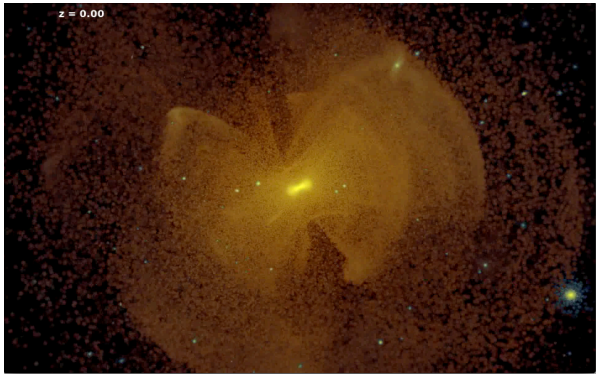












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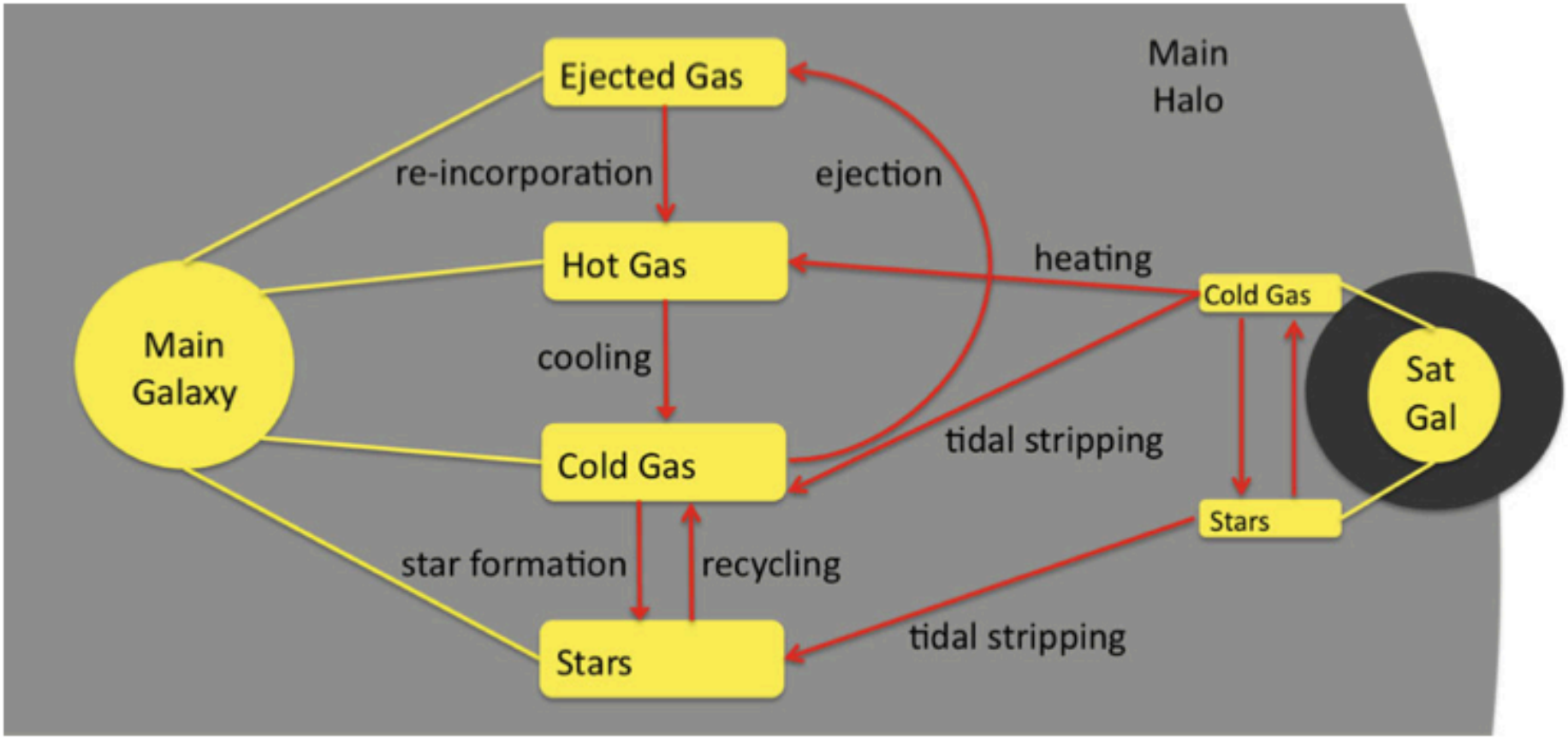
Semi-analytic models of the Milky Way



Starkenburg et al., 2013

Why semi-analytical modelling?

- Requires much less computational power than hydrodynamical models – yet relies on similar "sub-grid" physics
  - Better resolution / larger volumes possible
  - Can serve as toy model to test out physical prescriptions
  - Gives intuition for physical processes
  - What is missing?

- Why study the satellites with this technique?
  - Better resolution – can resolve smaller satellites in MW system
  - Several physical prescriptions become important at this scale
    - Stellar stripping, ram-pressure & satellite disruption
    - Sensitivity to reionization & feedback

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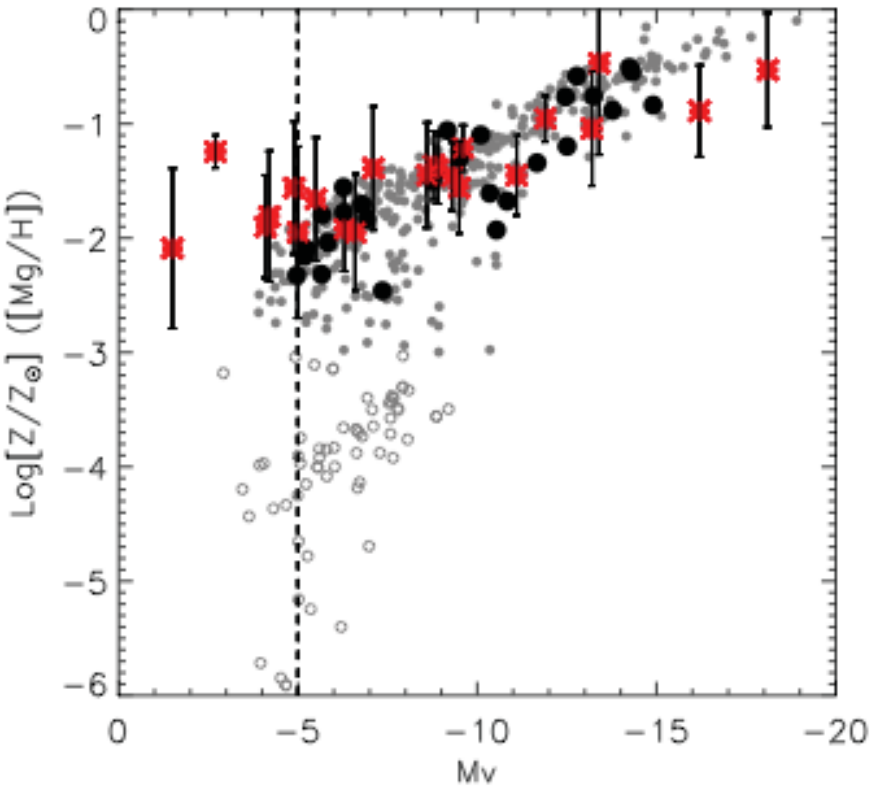
- BUT…. Several prescriptions can not be modelled
  - Substructures within the satellites
  - The effects of baryons on the dark matter structure (core-cusp debate)

Our model

- Starkenburg et al., 2013

Based on Kauffmann et al. (1999), Springel et al. (2001), De Lucia, Kauffmann & White (2004), Croton et al. (2006), De Lucia & Blaizot (2007), De Lucia & Helmi (2008) and Li et al. (2009, 2010)

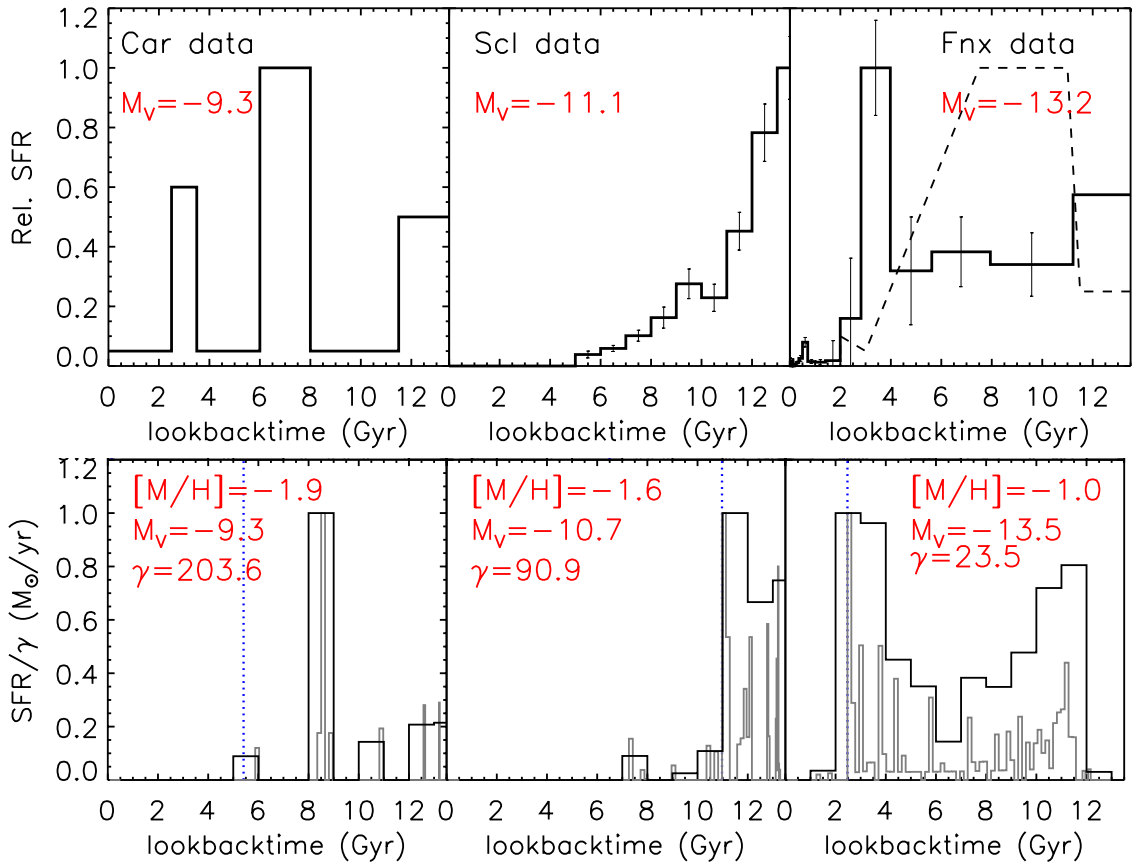
- Branch of the "L-Galaxies model" or "Munich(/ Groningen) model"
  - Developed for much larger scales
  - Including new physical prescriptions satellite stripping & disruption



Finding the MW satellites

- Star formation histories continuous & bursty, early & late

Starkenburg et al., 2013b



- Including chemical evolution modelling (Romano & Starkenburg 2013; Romano, Bellazzini, Starkenburg & Leaman 2015)

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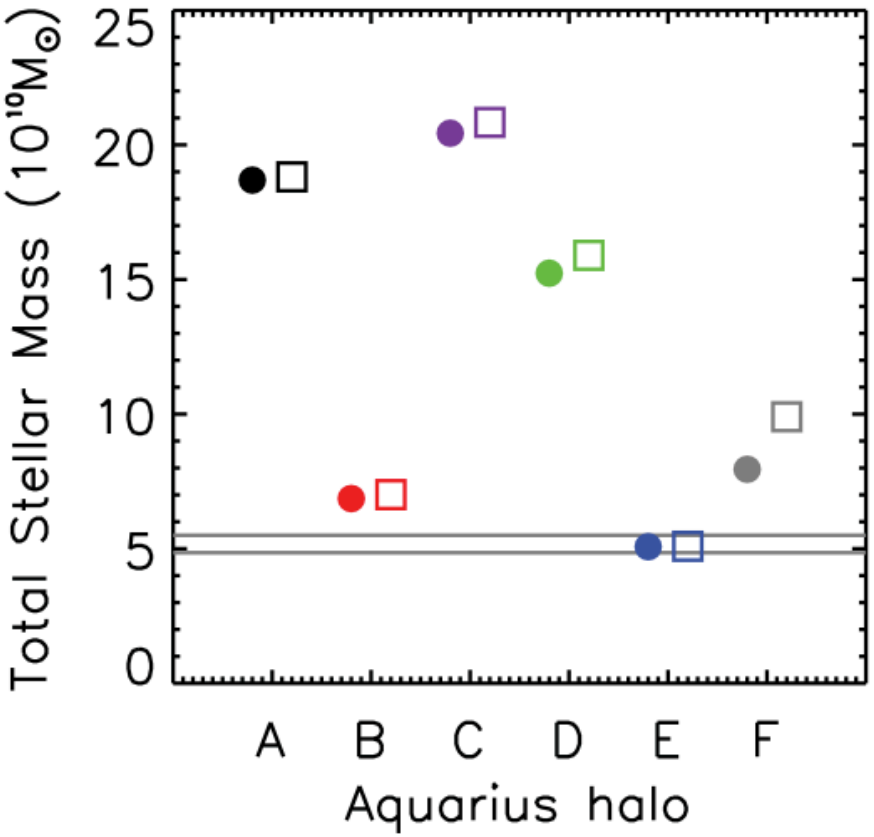
How massive should the galaxy be?

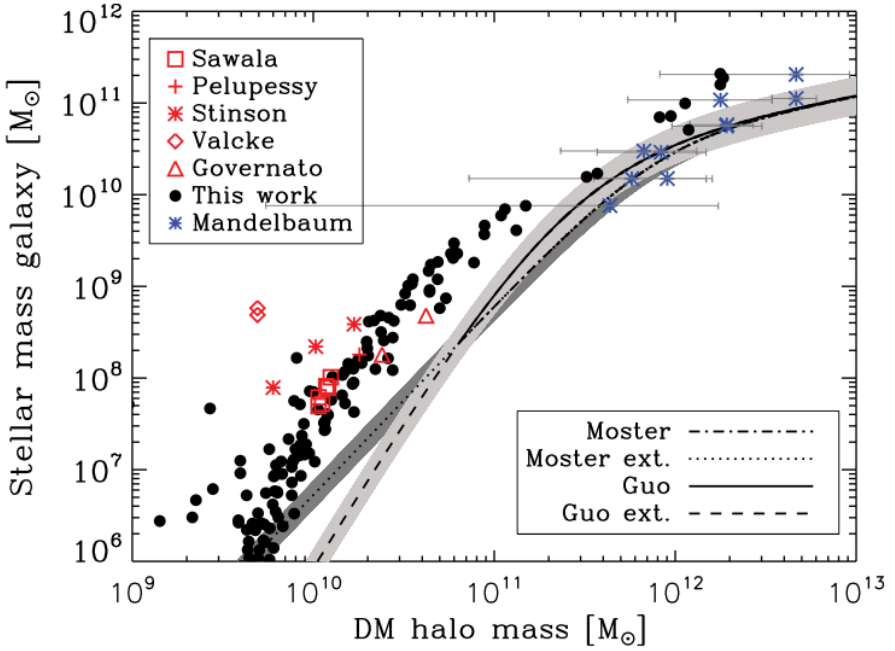
- Milky Way mass is uncertain
  - Which halo should contain a Milky Way galaxy?
  - We agree better with a light MW, also for the too-big-to-fail (Vera-Ciro et al., 2013)
  - Discrepancy of factors up to ~10 between models that all do reproduce nice luminosity functions & metallicity relations
  - Not unique to semi-analytics



Starkenburg et al., 2013b

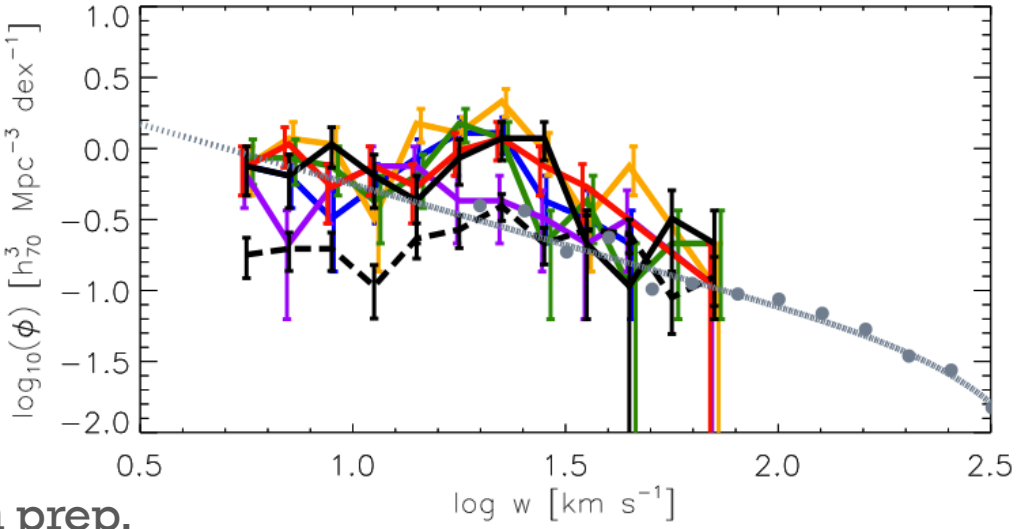
Who lives in which halo?

- Hydrodynamical simulations and abundance matching tend not to agree
  - We agree more with hydro



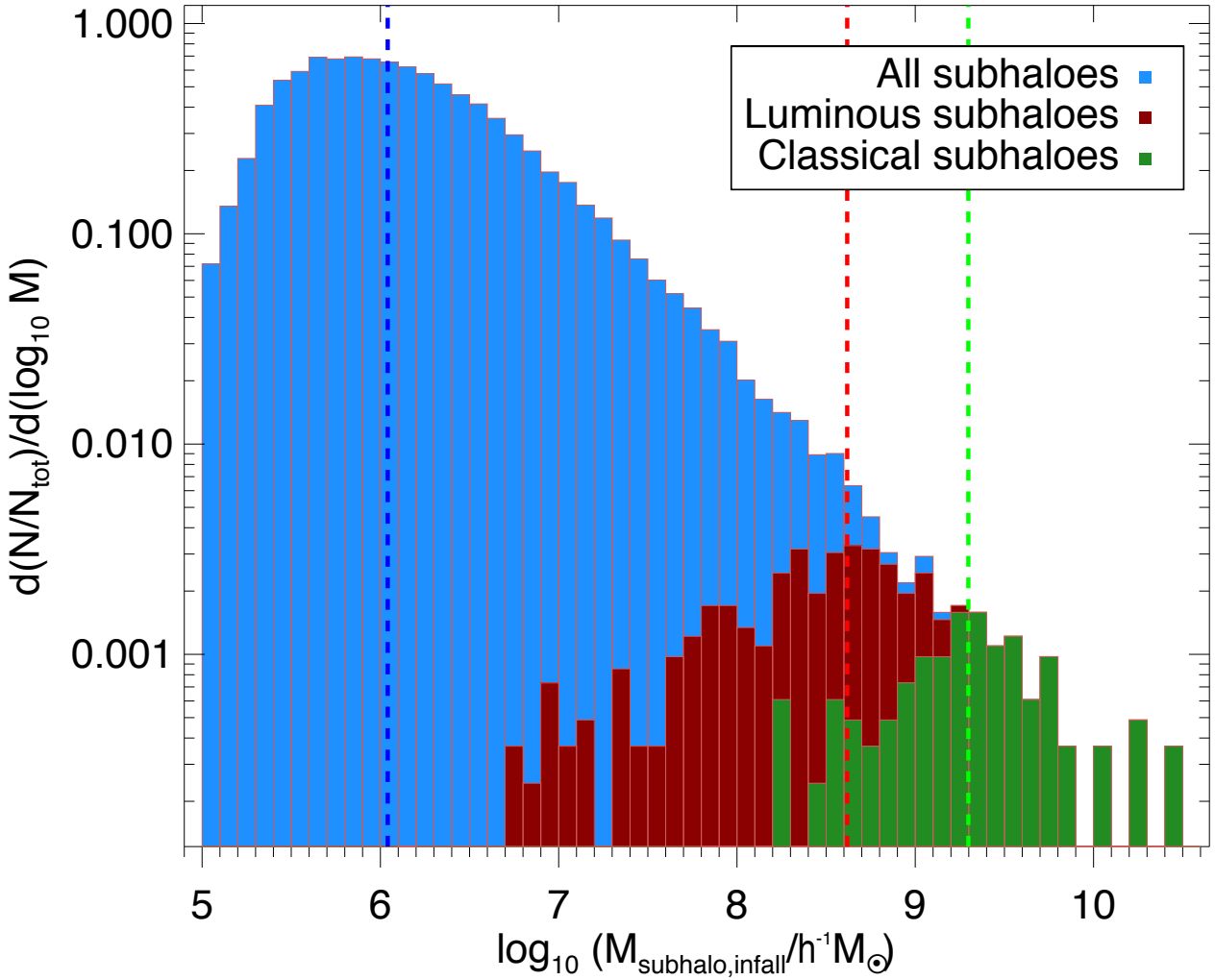
Starkenburg et al., 2013b

- Finding other ways to test this relationship
  - Atomic hydrogen rotation curves
  - Comparison with ALFALFA



Yaryura, Helmi, Abadi & Starkenburg, in prep.

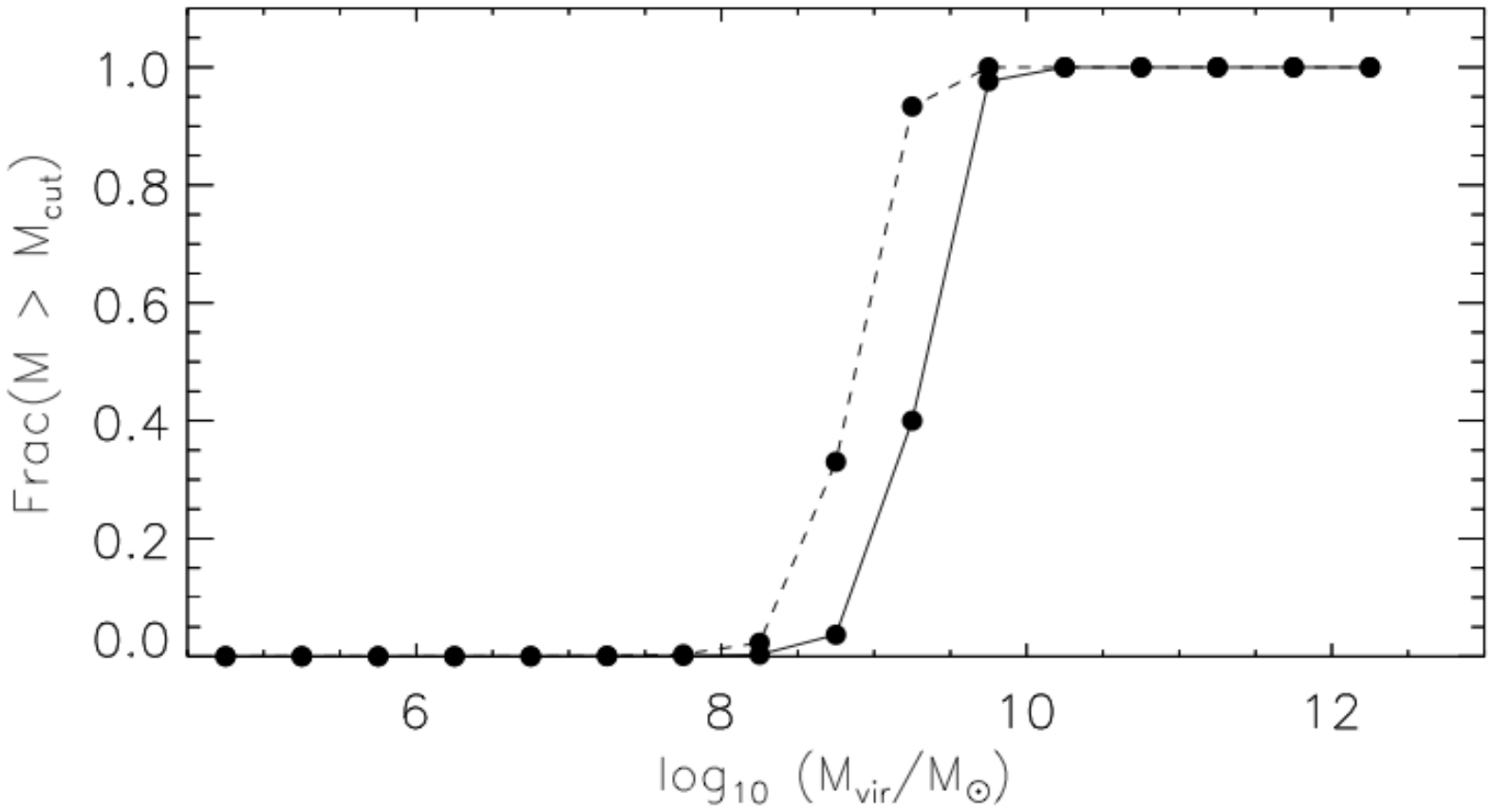
The galaxy mass – halo mass relation



This is also means the slope of the power-law will be different!

Barber, Starkenburg, Navarro et al., 2014

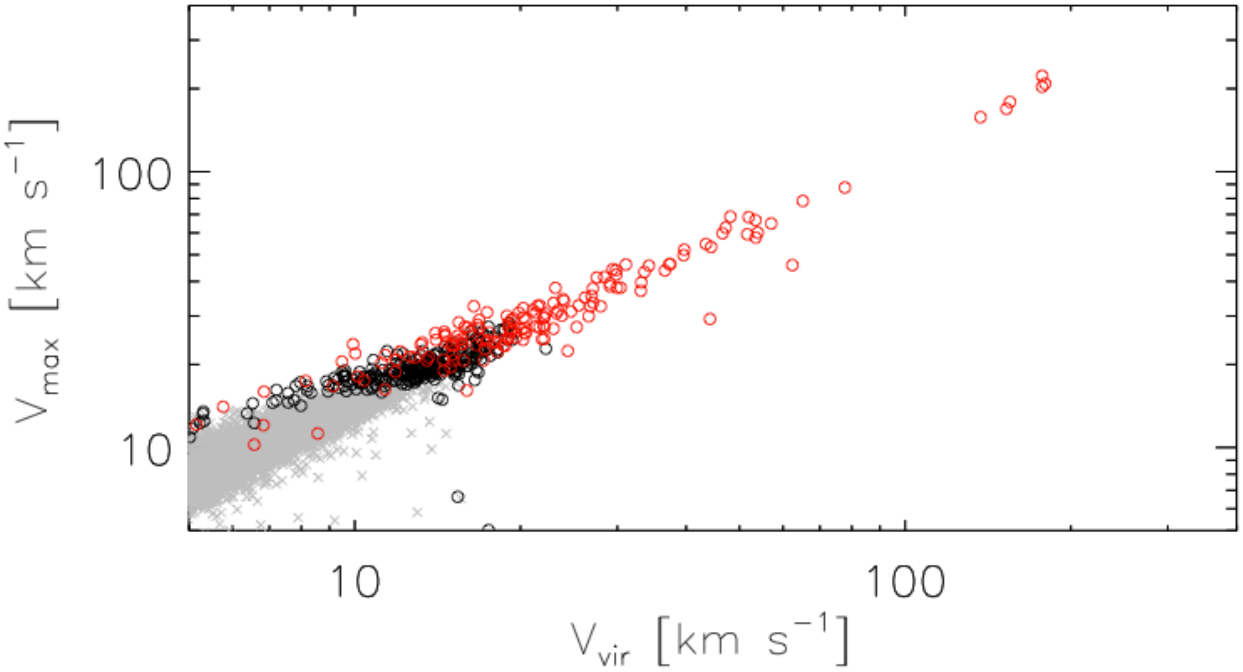
The galaxy mass – halo mass relation



Yaryura, Helmi, Abadi & Starkenburg, in prep.

The galaxy mass – halo mass relation

- Abundance matching techniques break down at lowest masses
  - History of the individual halo matters (see also Sawala et al., 2015)

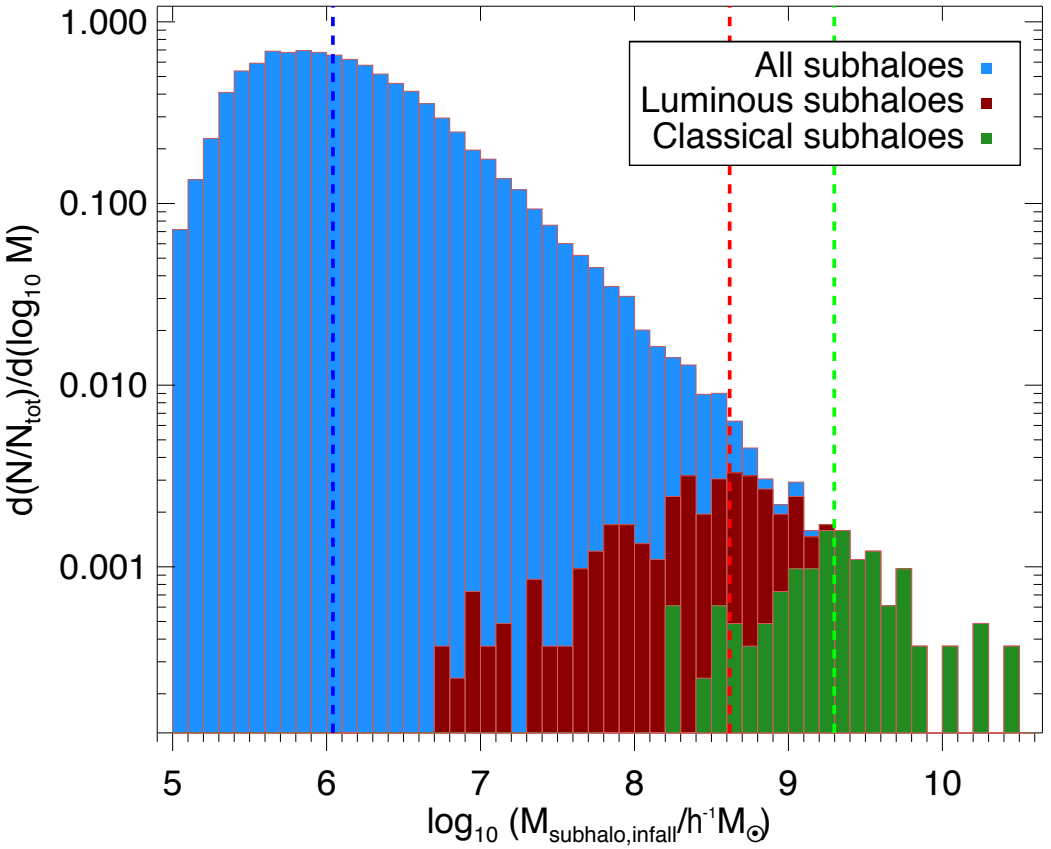


Yaryura, Helmi, Abadi & Starkenburg, in prep.

The orbits, shapes & orientations of satellites

Barber, Starkenburg, Navarro et al., 2014, 2015

- Let's use the model to tell us just which satellites are interesting
- What can we say from their dark matter properties?

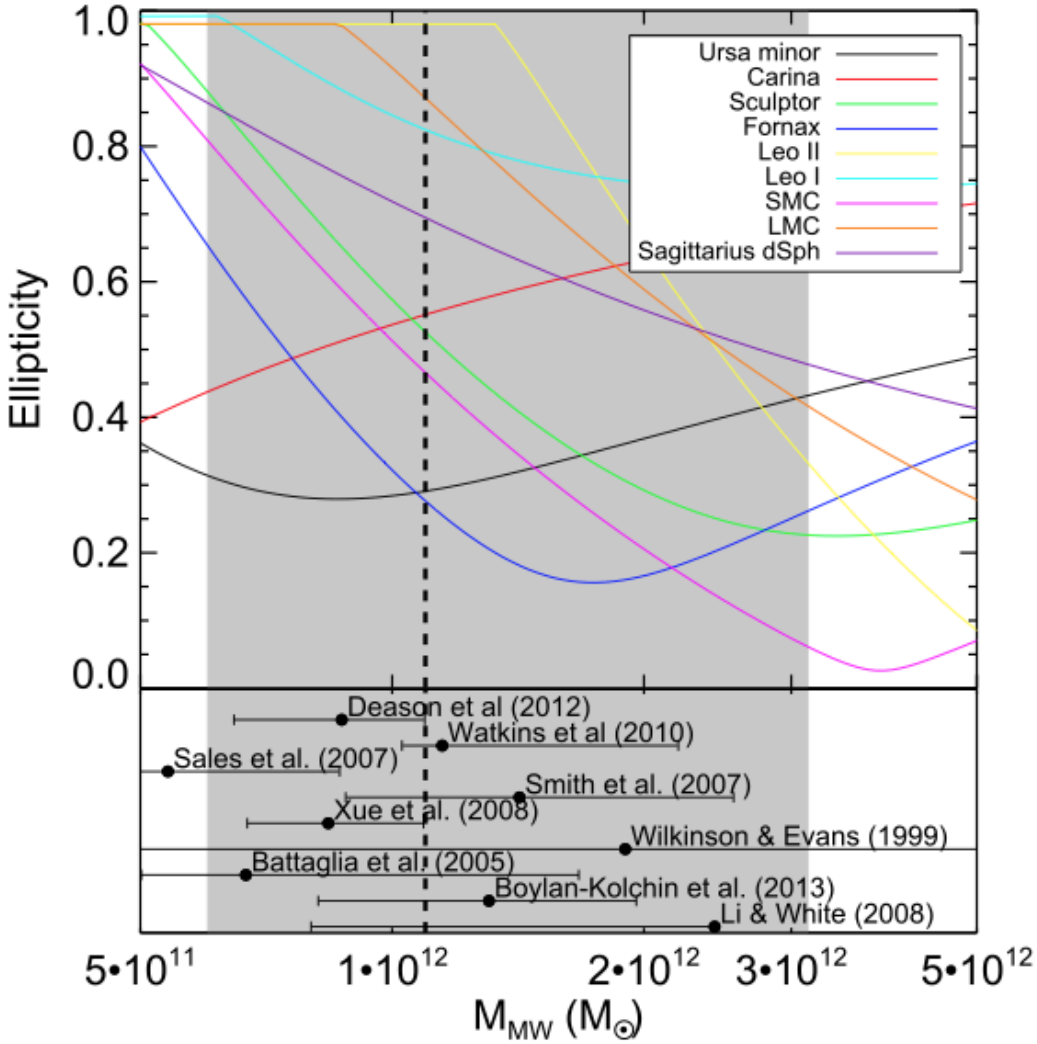


Barber, Starkenburg, Navarro, McConnachie, Fattahi, 2014

How do satellites' orbits help?

Barber, Starkenburg, Navarro et al., 2014, 2015

- Can orbits be linked to star formation enhancement or surpression?
  - Proper motions are only half the story
  - This can actually be used to constrain the Milky Way mass too



Barber, Starkenburg, Navarro, McConnachie, Fattahi, 2014

Conclusions

- Semi-analytical modelling can be very useful as toy models to test physics & gain intuition
  - The unknown dark matter mass of the Milky Way and the satellites are a limiting factor in the modelling
  - Our model reproduces various observables, using the properties of stars and of HI gas
  - A natural result of input physics is the breakdown of abundance matching at low masses
- The satellites' orbits rely on the Milky Way mass too
  - Satellites become actually rounder through stripping
  - Find a Milky Way mass for which orbits "match"