Dark Matter

ASTR 333/433

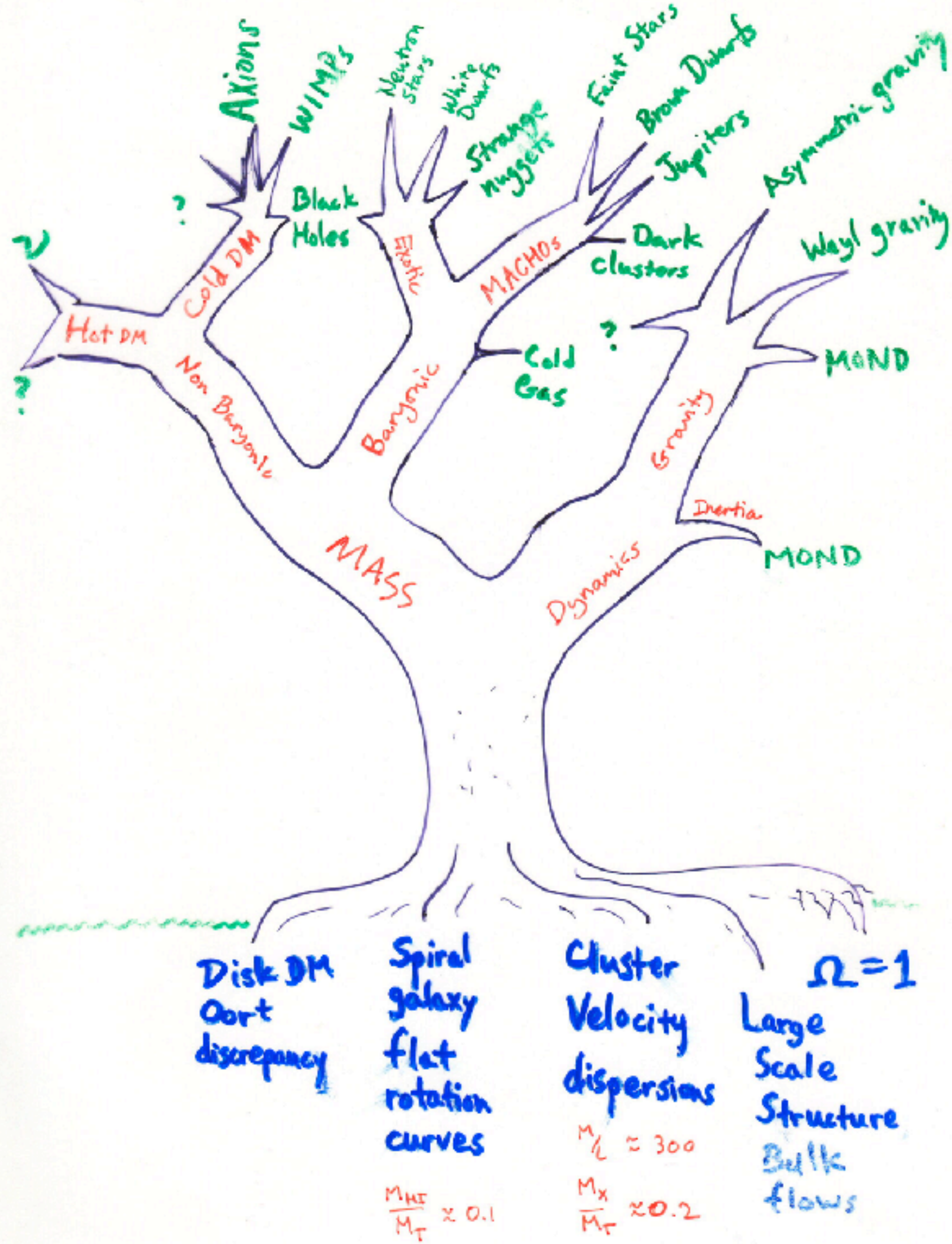
Today

Too Big to Fail
Satellite Planes
Tidal Dwarfs

4/5: Homework 3 due

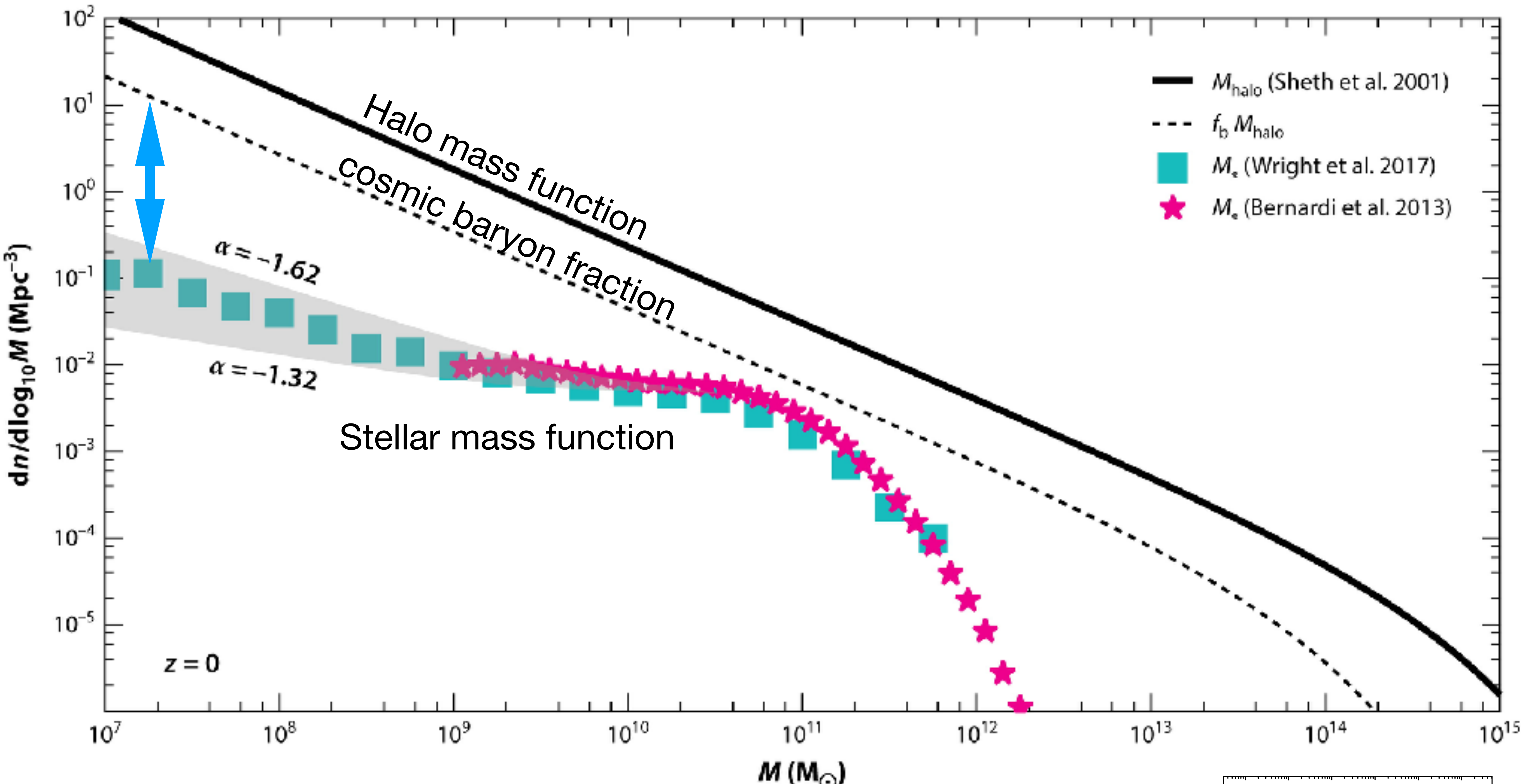
ASTR 433 Projects
4/17: distribute abstracts
4/19: 20 minute talks

4/24: Homework 4 due
4/26: Exam



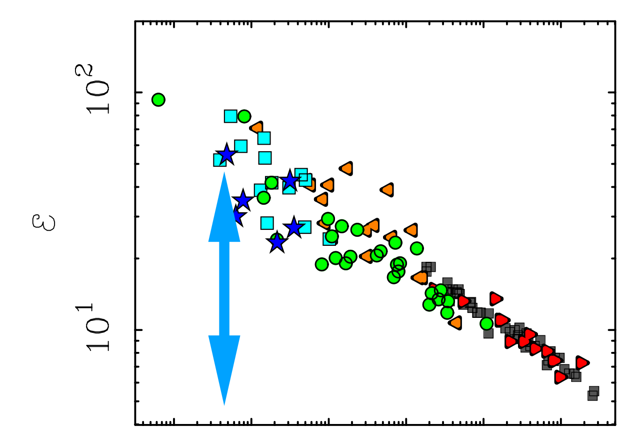
Halo and stellar mass function

(Bullock & Boylan-Kolchin)



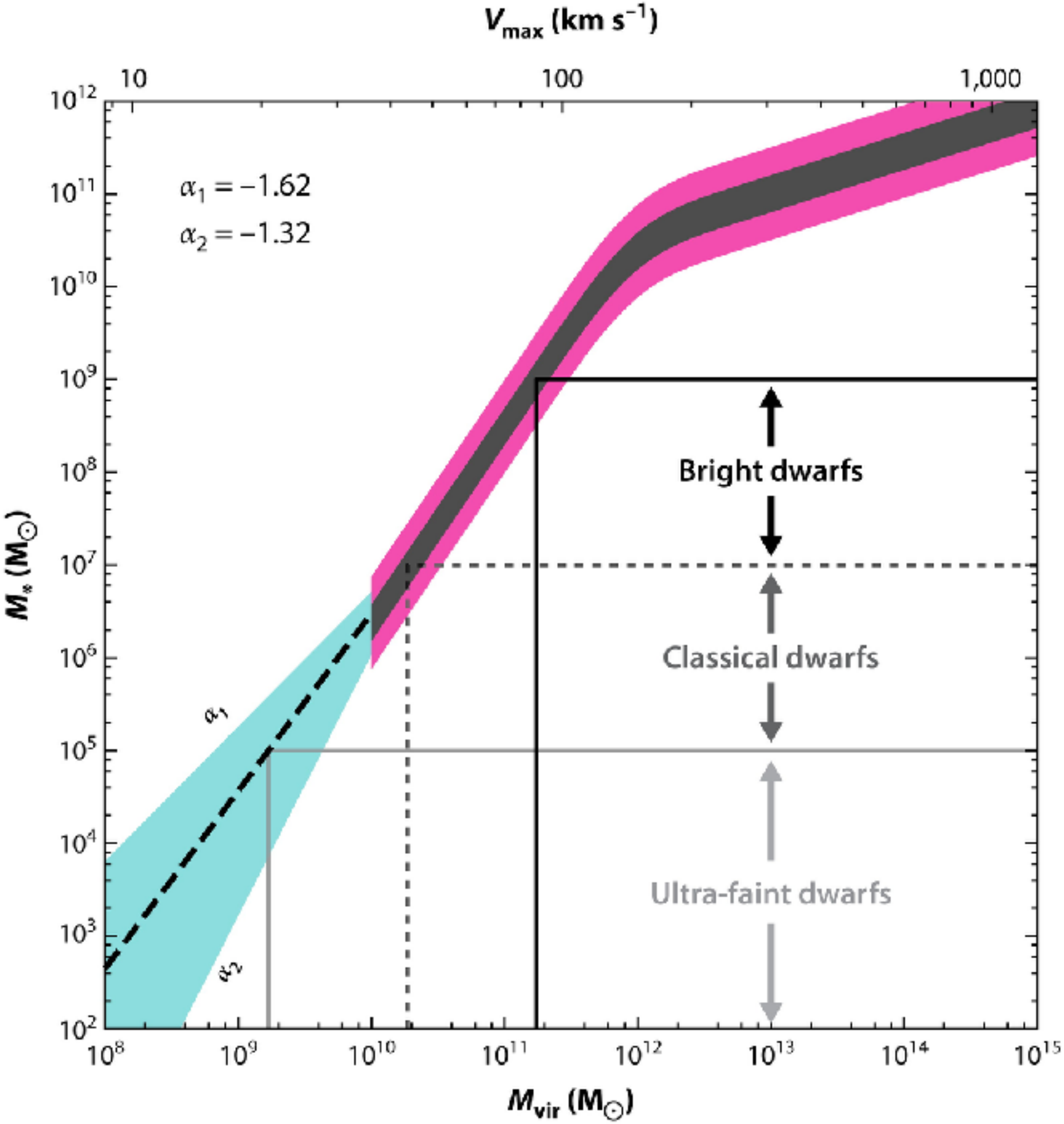
Bullock JS, Boylan-Kolchin M. 2017.
Annu. Rev. Astron. Astrophys. 55:343–87

Same problem as with dynamics:
too few baryons for the dark mass



Abundance Matching

(Behroozi; by way of Bullock & Boylan-Kolchin)



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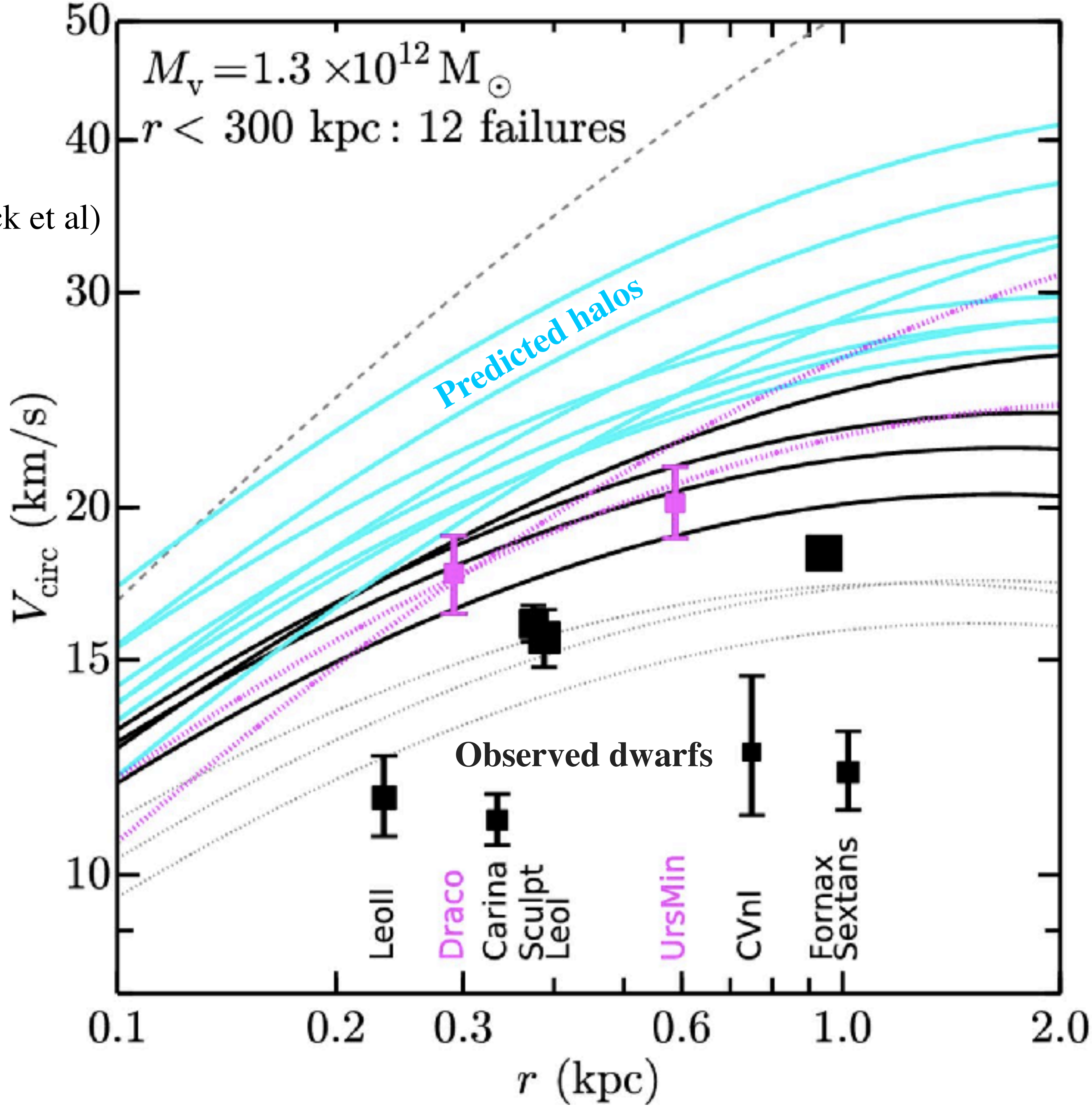
Too Big to Fail?

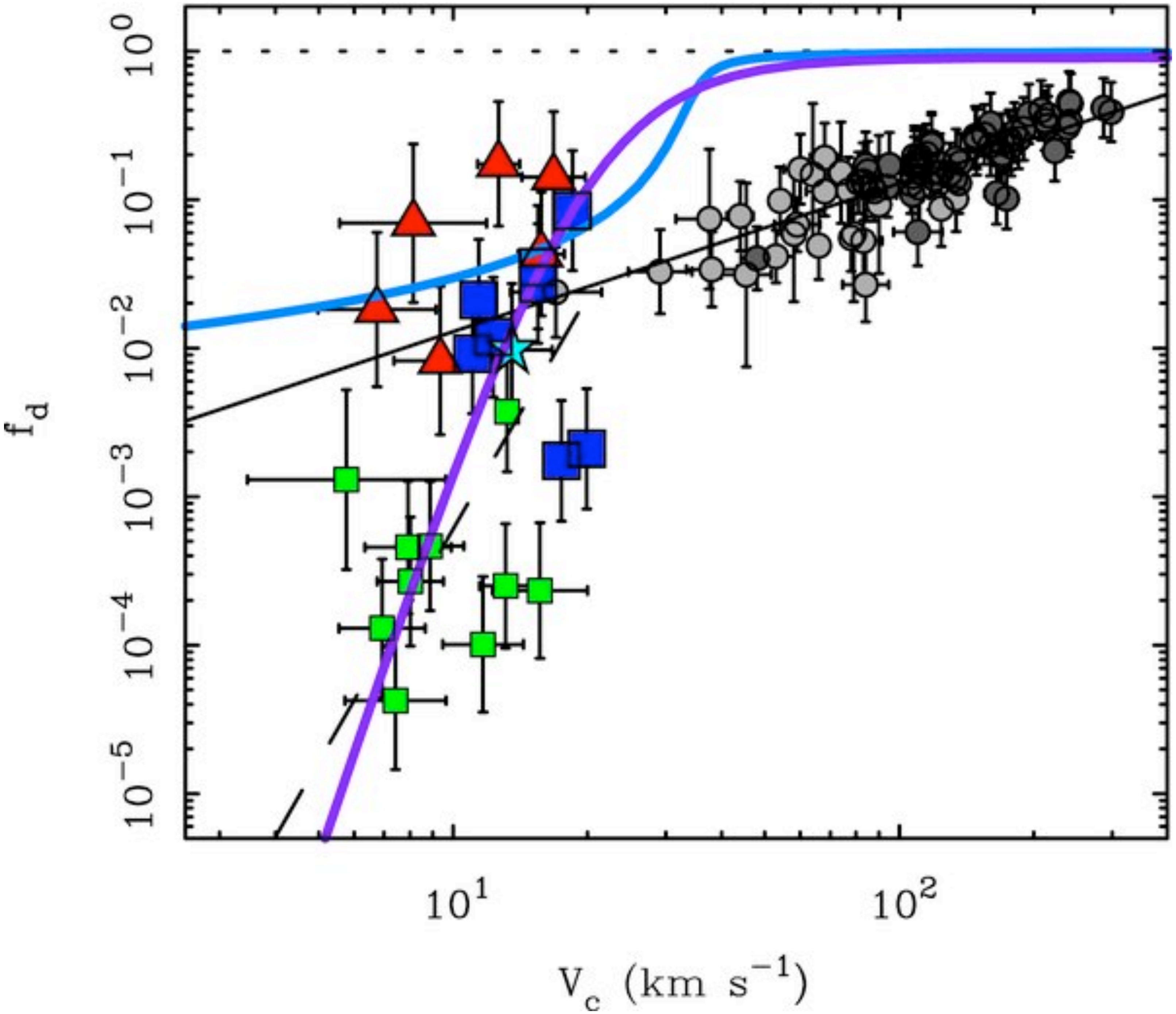
To Big To Fail

(Bovill & Ricotti;
Boylan-Kochlin & Bullock et al)

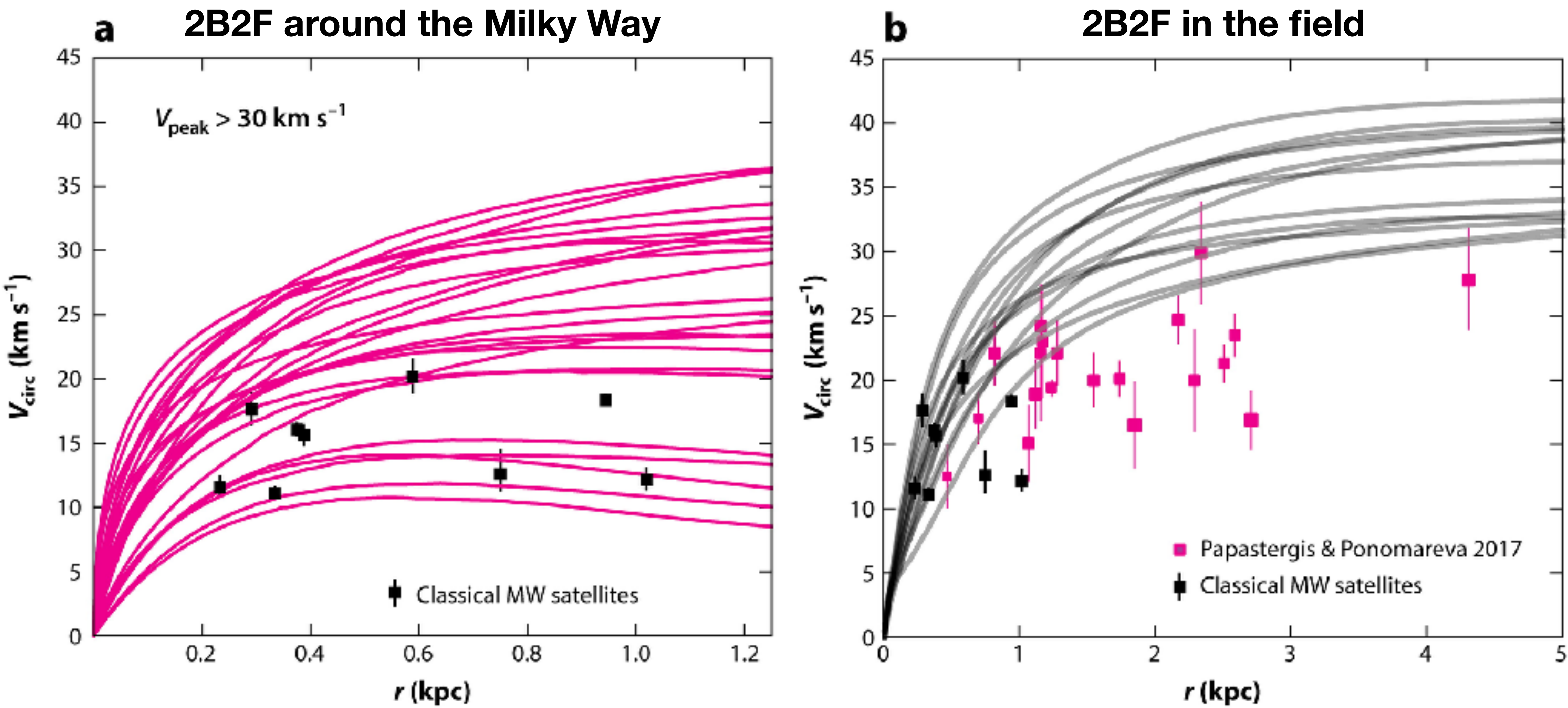
LCDM models predict many sub-halos that are denser & more massive than the observed dwarf satellites. If the little sub-halos managed to make dwarfs, why didn't these bigger ones?



Many models can be invoked to suppress galaxy formation in small dark matter halos; is harder to prevent in mid-size halos.



e.g., Reionization models illustrated here are good for explaining the smallest galaxies, but not ~40 km/s halos, which are too big to fail.



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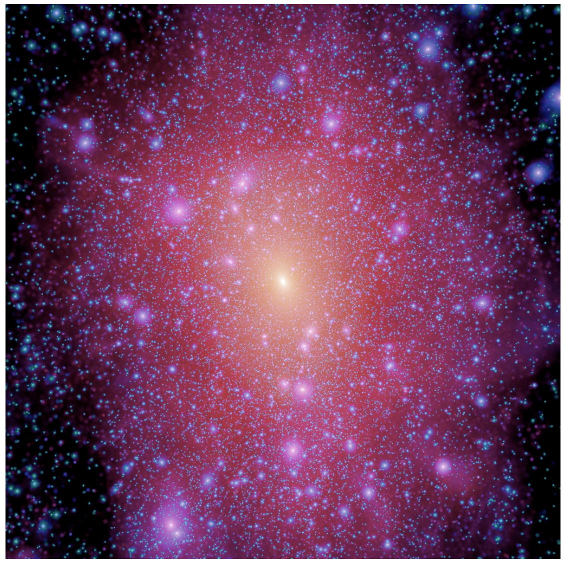
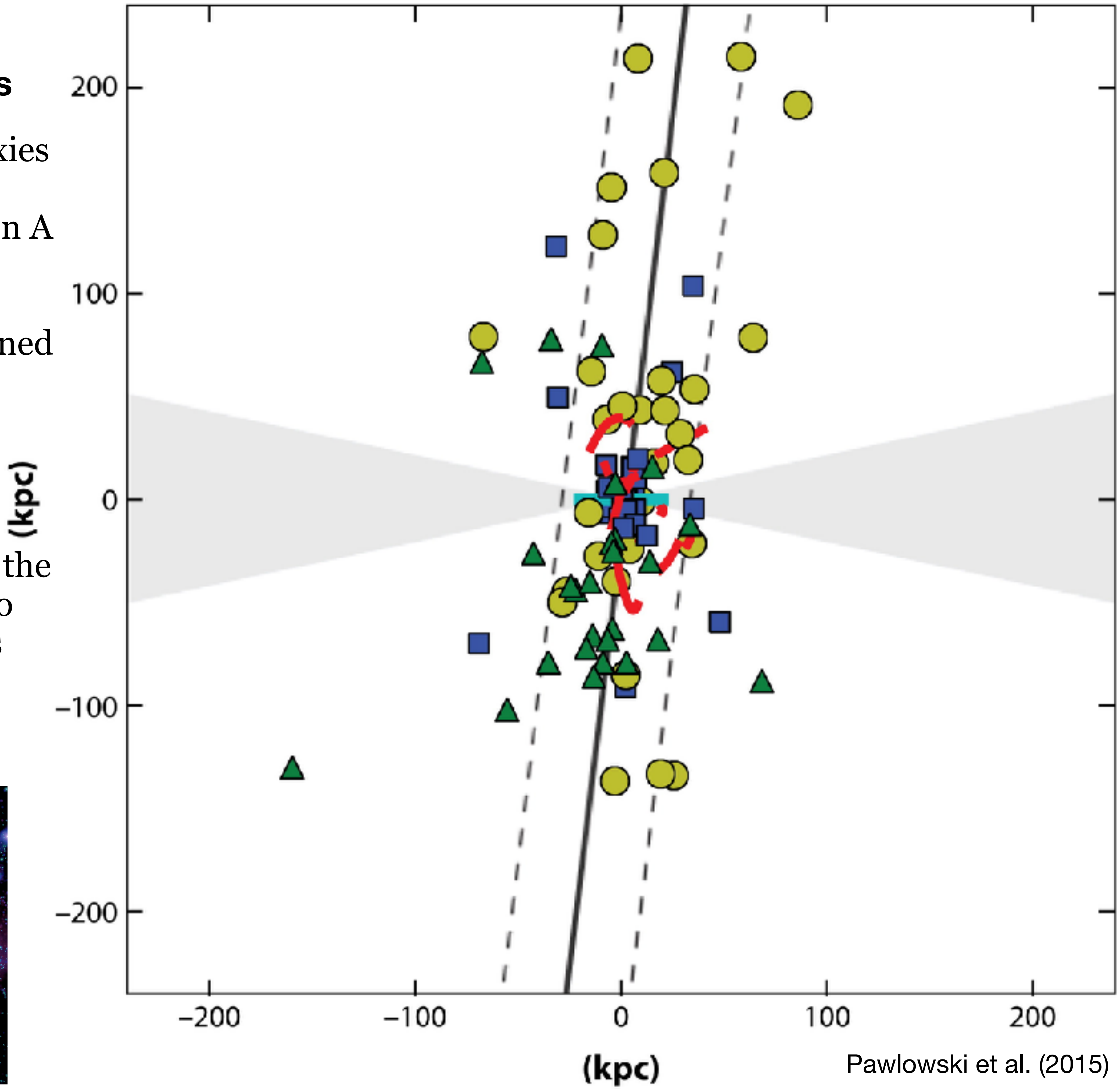
Too Big to Fail happens in the field, too. It can’t be a process specific to satellites. Sort of combines the missing satellite and cusp-core problems.

Planes of satellites

Dwarf satellite galaxies of the Milky Way, Andromeda, and Cen A are observed to be orbiting on quasi-circular orbits confined to narrow planes.

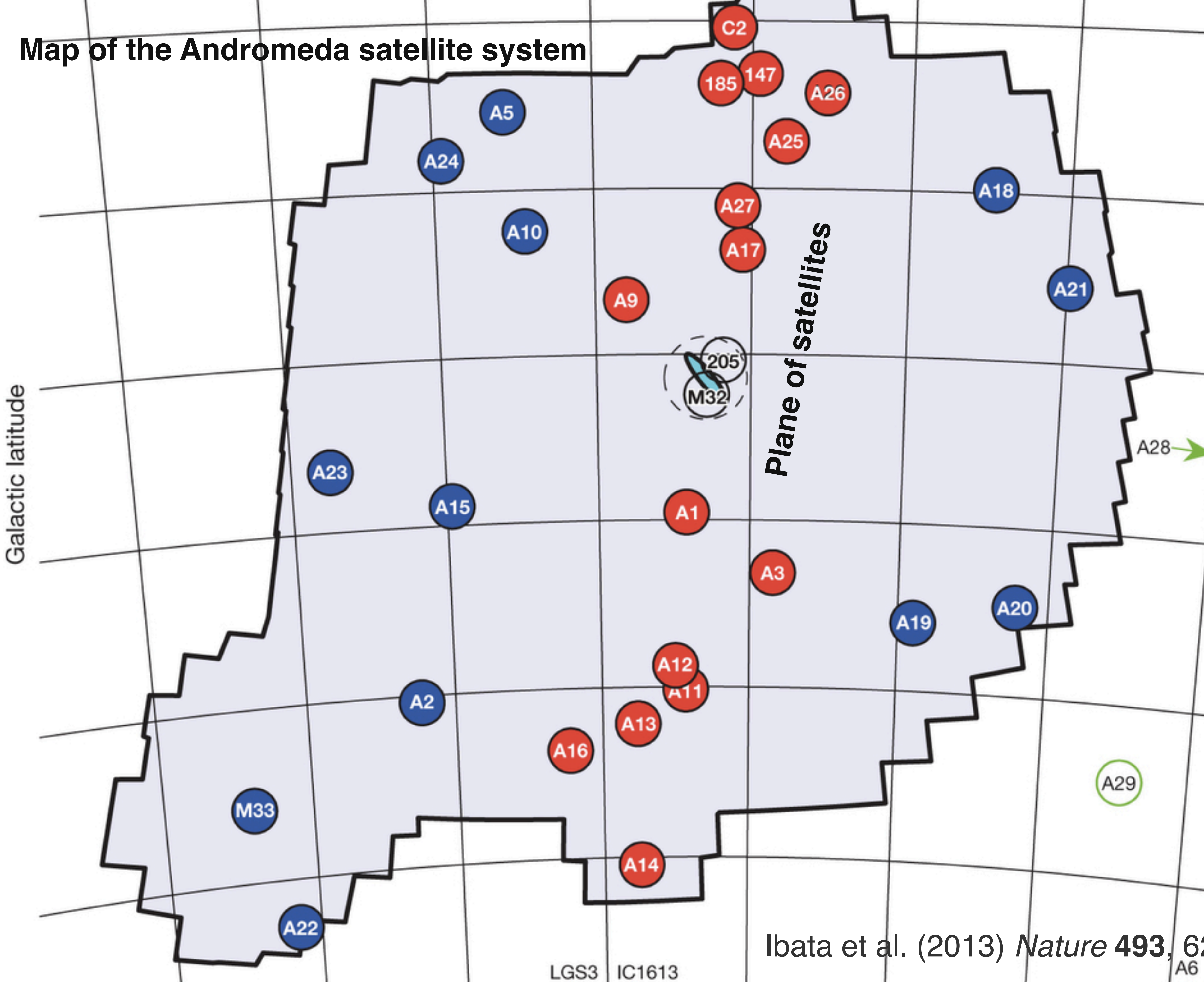
In DM simulations, the sub-halos thought to host dwarf satellites have highly radial orbits that are randomly oriented.





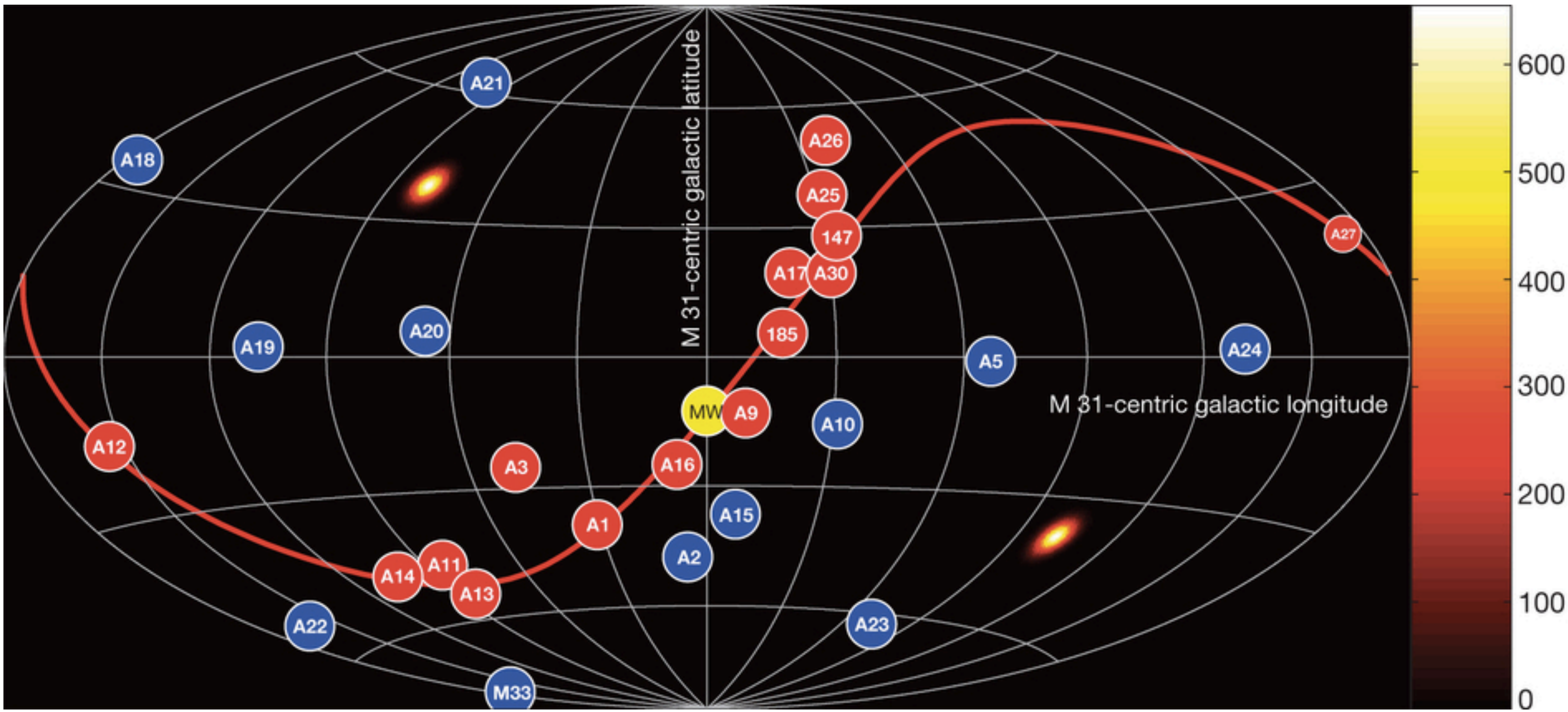
Pawlowski et al. (2015)

Map of the Andromeda satellite system



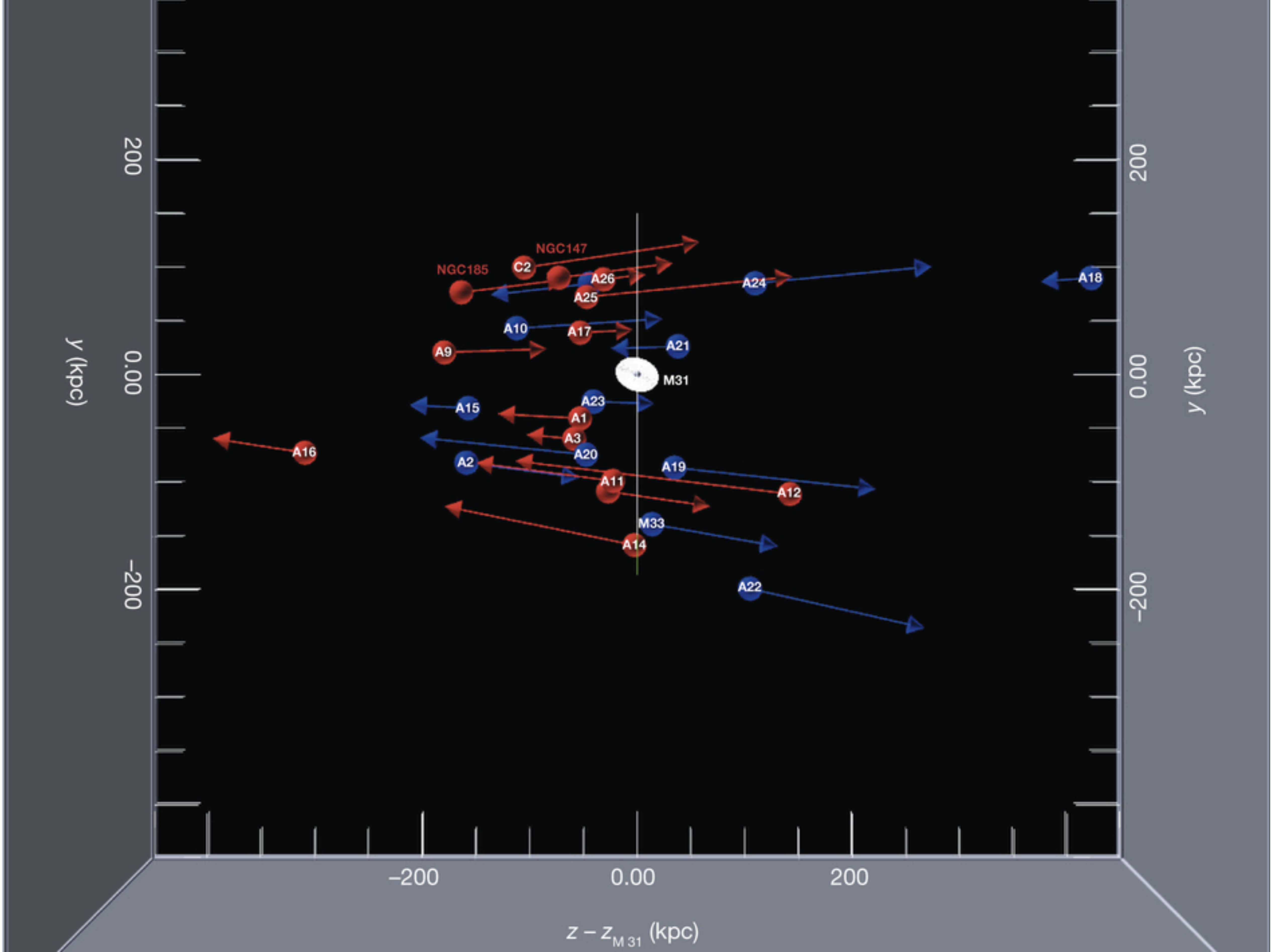
Ibata et al. (2013) *Nature* **493**, 62

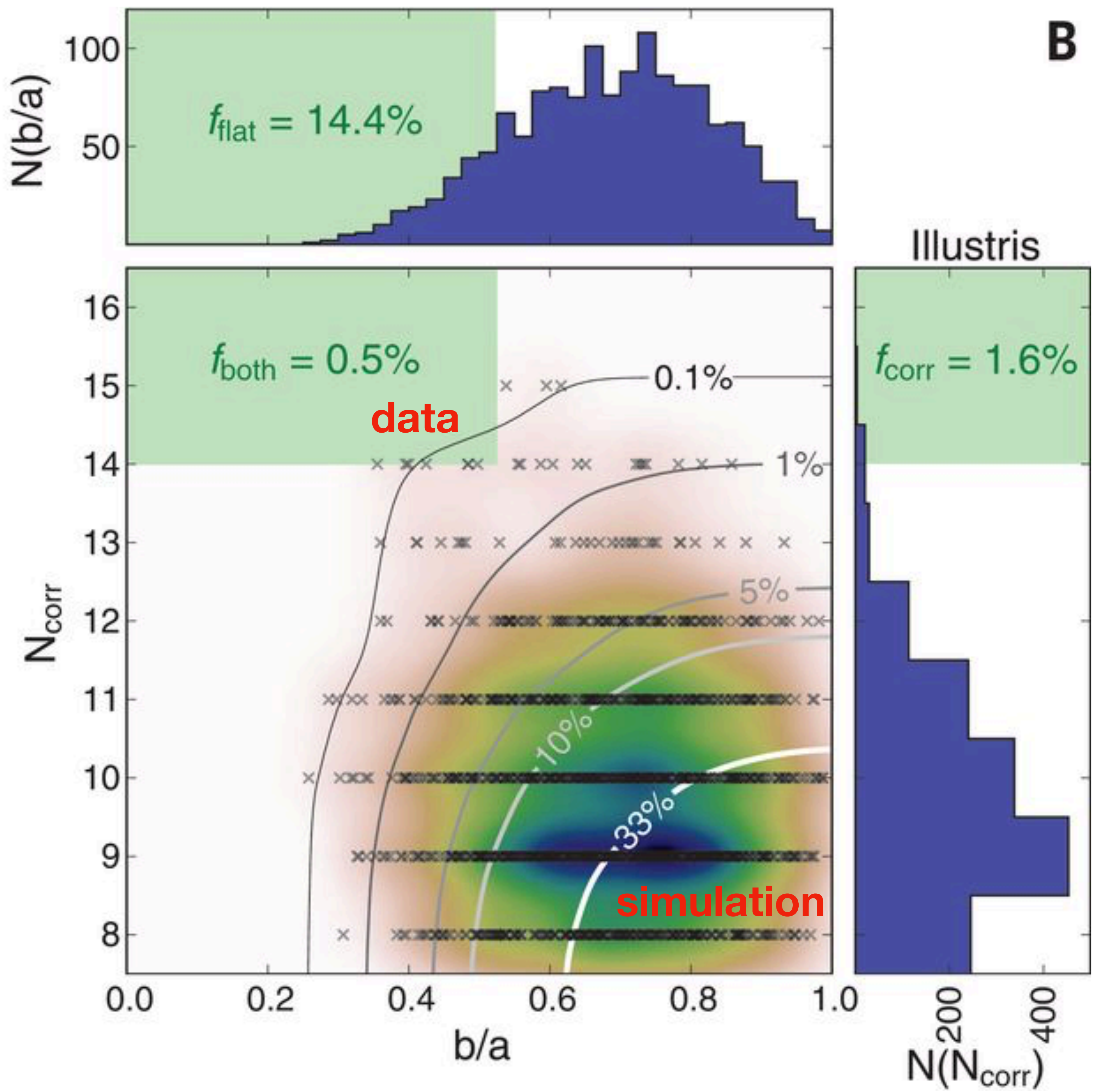
Satellite galaxy positions as viewed from Andromeda



Ibata et al. (2013) *Nature* **493**, 62

The planar, rotating structure.





The chance of the satellite plane of Cen A being both as flattened and as kinematically correlated as observed is < 1% in simulations

(Müller et al. 2018 *Science*, **359**, 534)

Dwarf satellite galaxies are problematic for CDM in several ways:

- there should be thousands of them rather than dozens
  (missing satellite problem)

- they have shallow dark matter halo profiles
  (cusp/core problem)

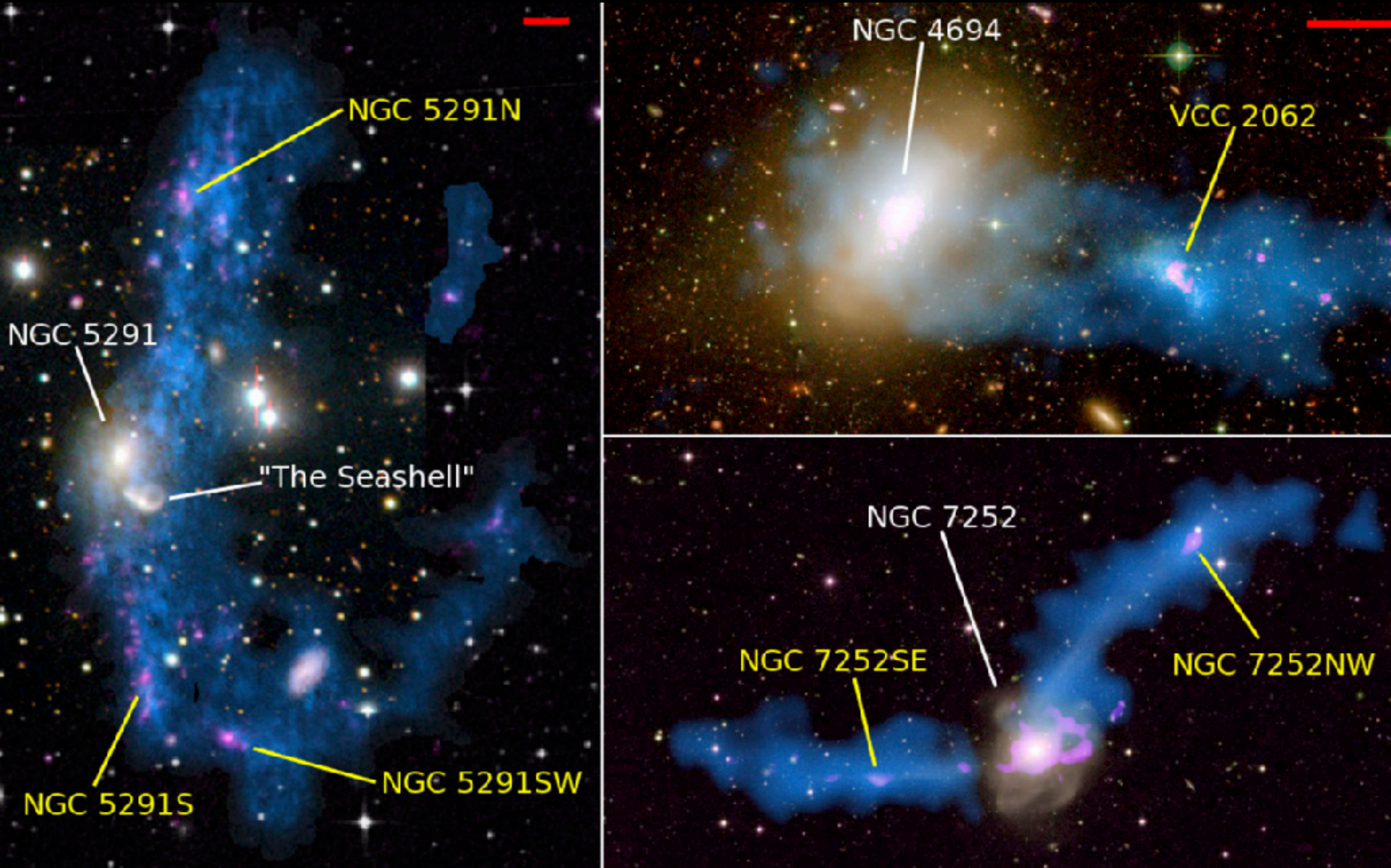
- Too Big to Fail
  (related to cusp/core problem)

- they tend to reside in co-orbiting planes
  (do not exhibit the expected isotropy in phase space)

Too Big to Fail is basically a restatement of the cusp-core problem, convolved with the missing satellite problem, which itself is a rephrasing of the luminosity function problem (flat rather than steep faint end slope).

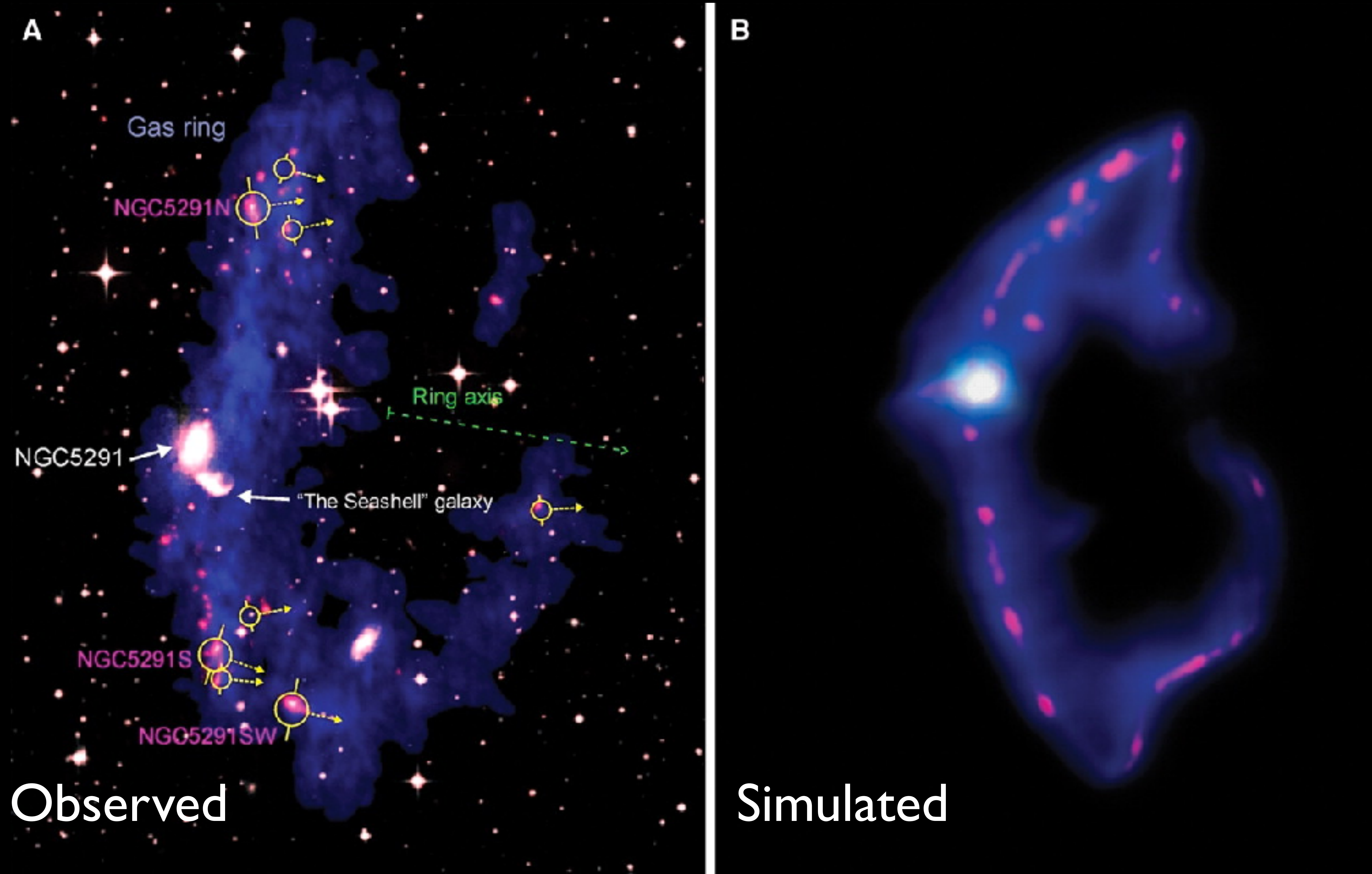
TDGs: Tidal Dwarf Galaxies

Lelli et al - see poster in hall!

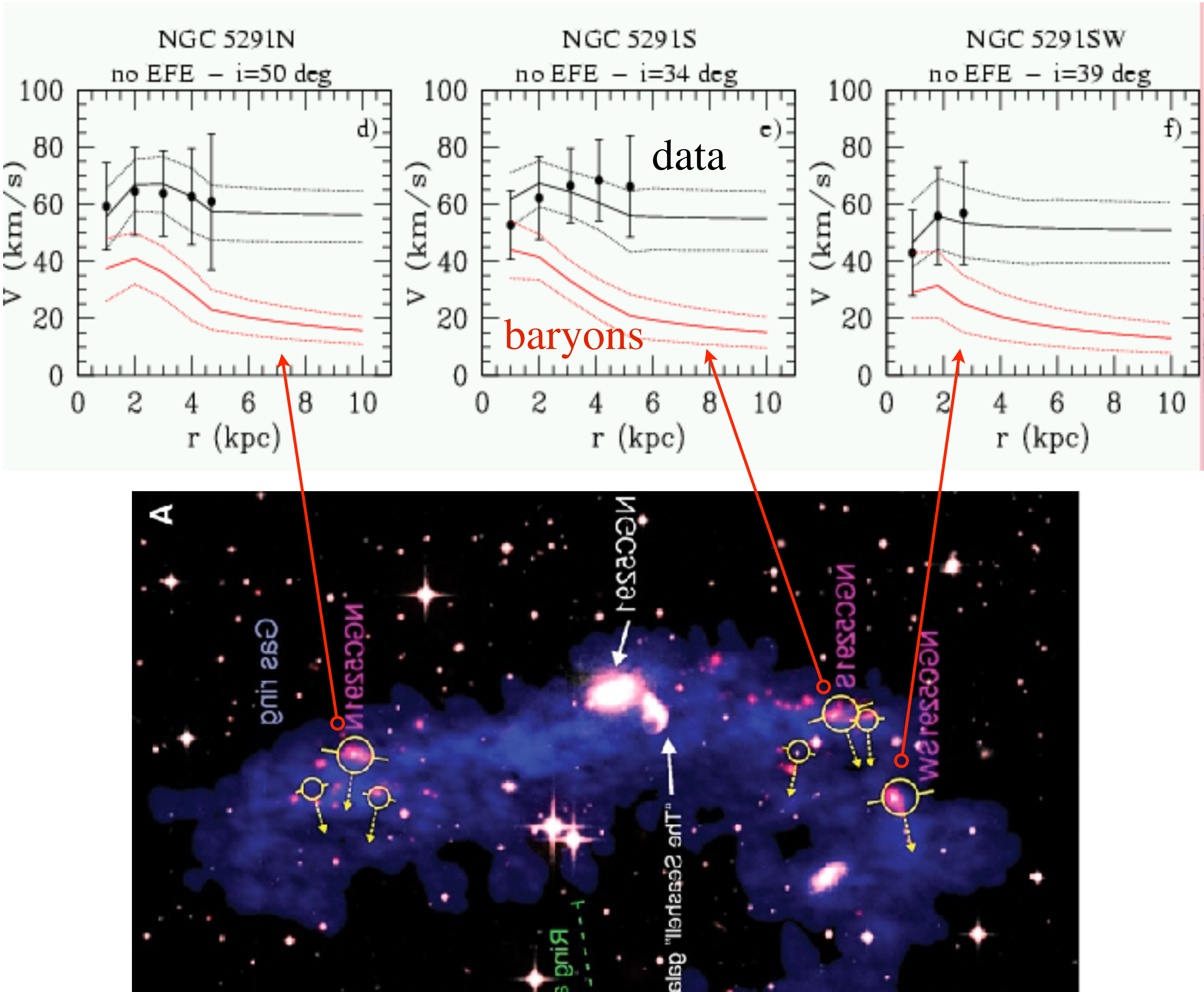


Tidal interactions often produce long, narrow streams of material extracted from the dynamically cold stellar and gas disk of the progenitor spiral(s). This material moves on very different orbits than the quasi-spherical DM halos. Consequently, TDGs formed from this material should be devoid of dark matter (DM only a few % of baryonic mass according to simulations of Bernaud et al.)

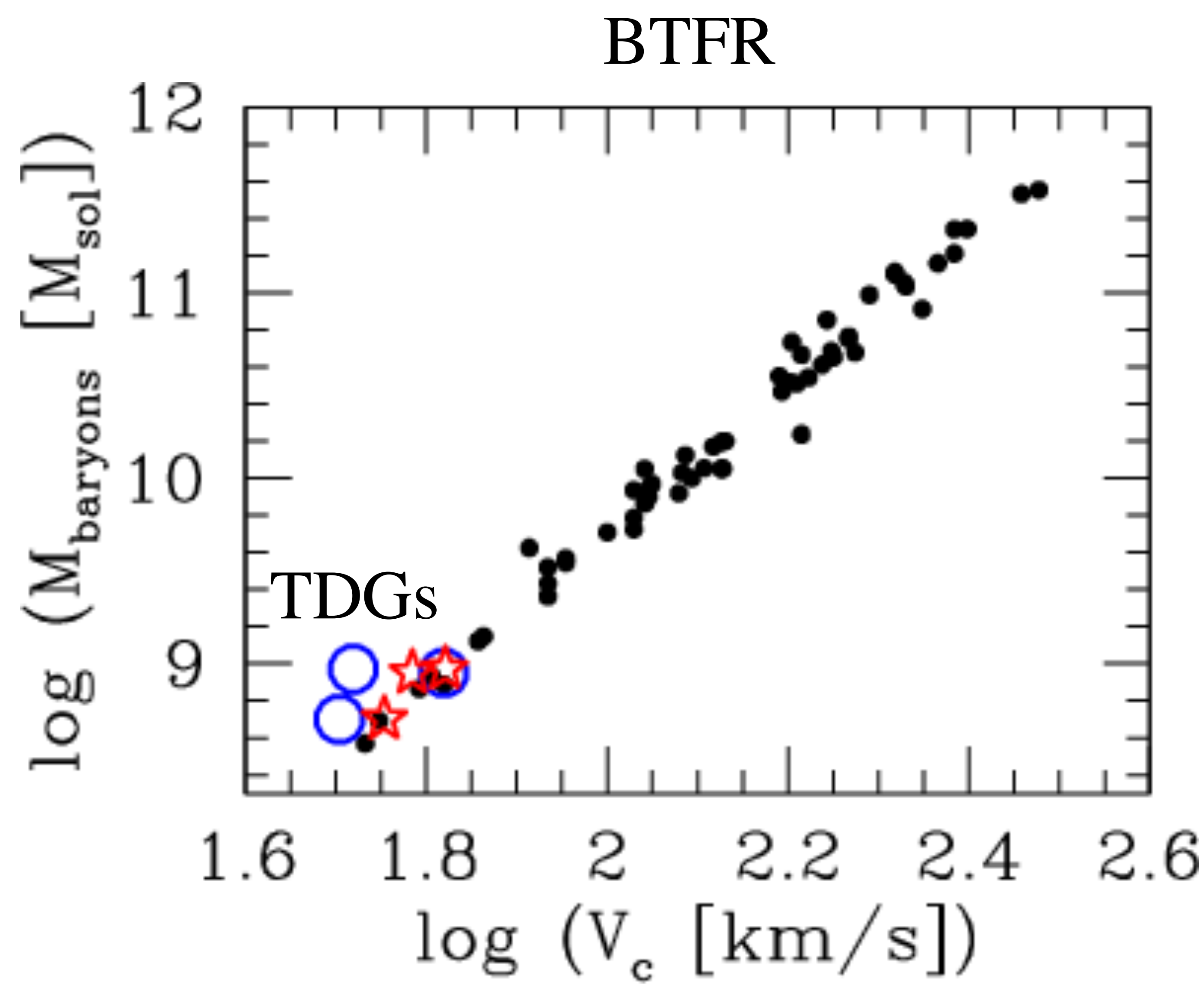
TDGs can form in the debris of tidal interactions. In this case, TDG candidates (pink) appear to have condensed from HI ring flung out by interaction



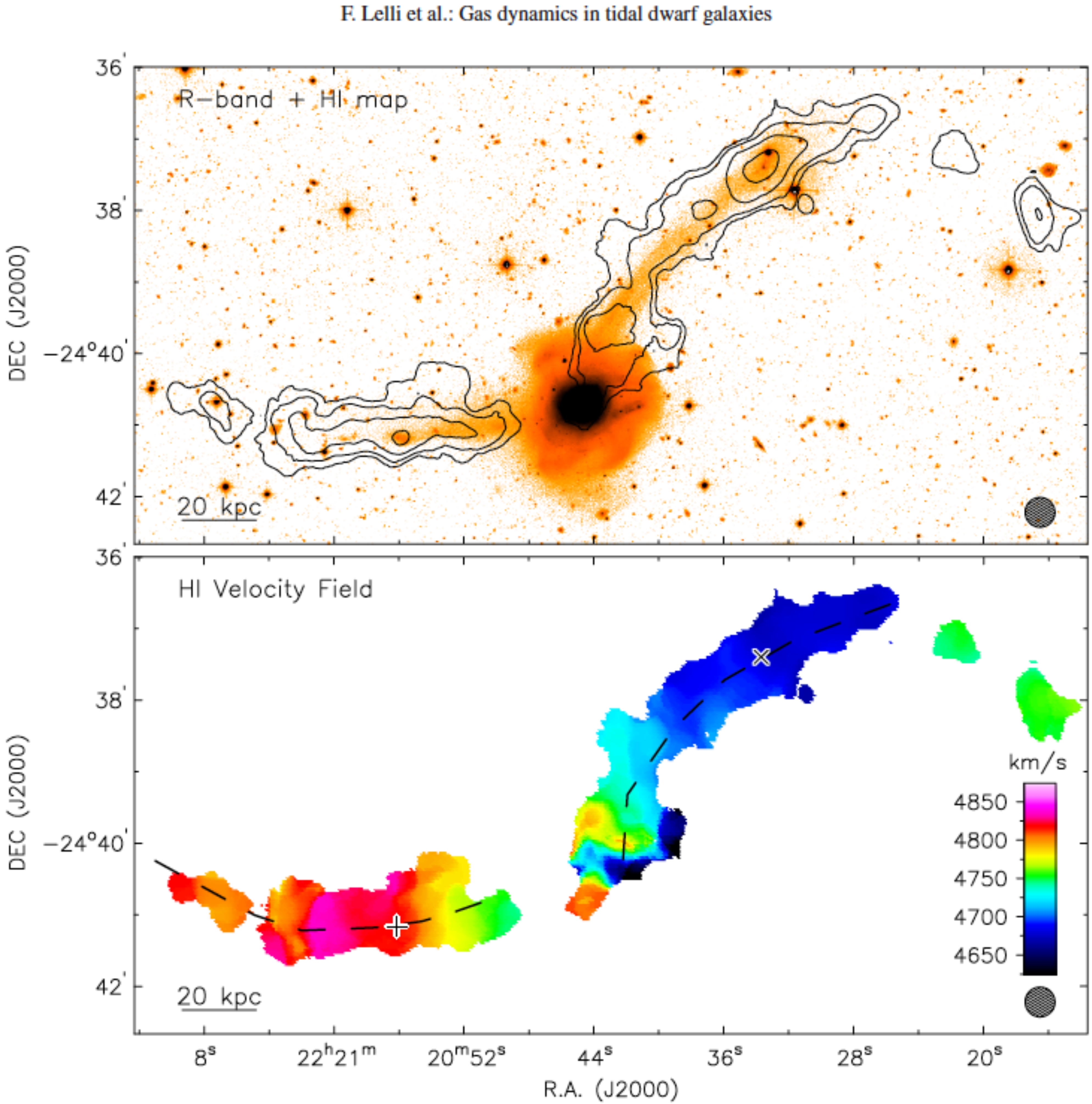
Prediction: rotation curves of TDGs should be as predicted by observed baryons.
Ironically, the absence of dark matter in TDGs would be evidence for dark matter.

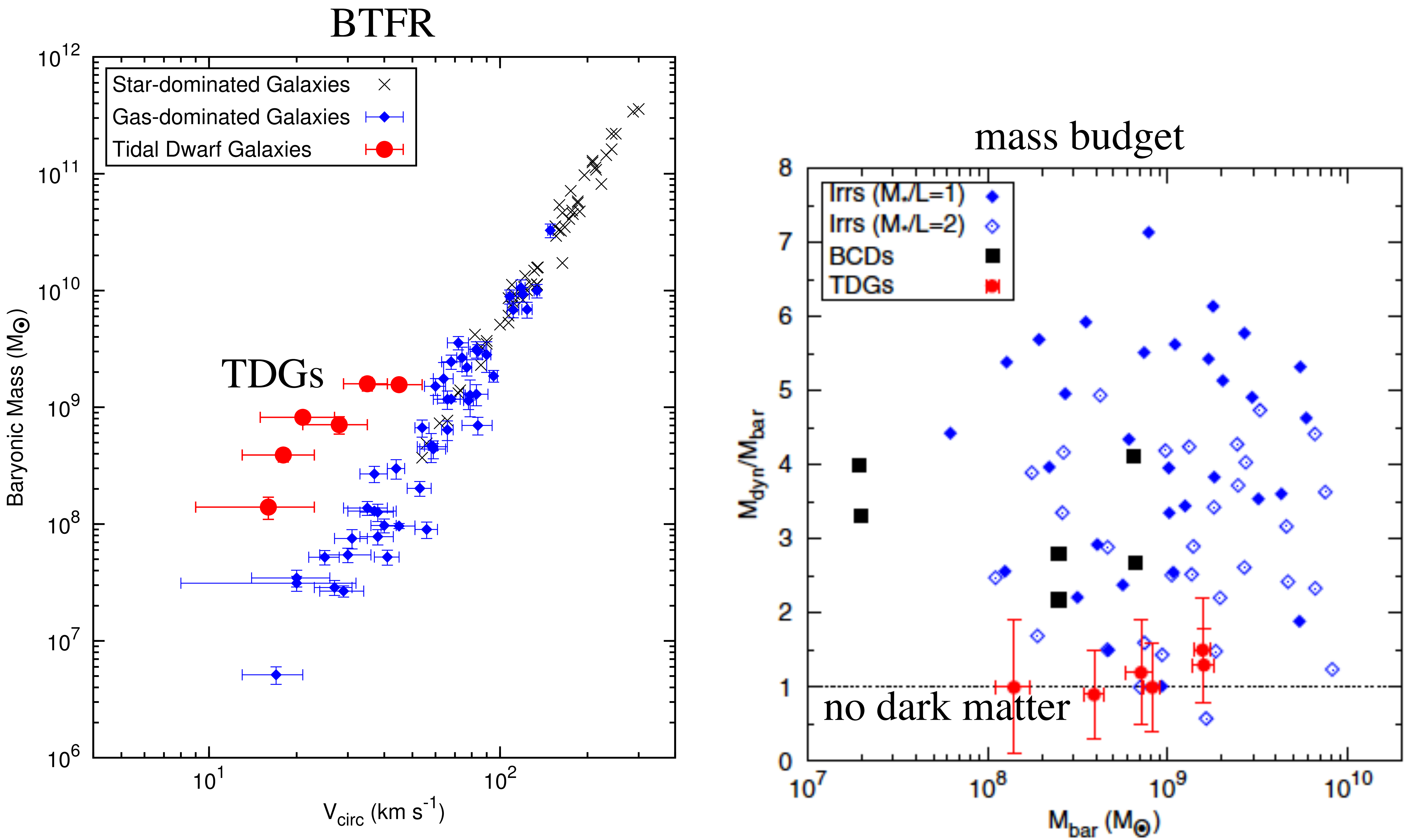


Gentile et al. (2007) found TDGs to be consistent with the baryonic Tully-Fisher - as expected for isolated galaxies, NOT for TDGs. Weird.



Lelli et al. (2015) examined more TDGs. Found the opposite - TDGs deviate from BTFR in the expected sense (slower rotators with mass consistent with just baryons)

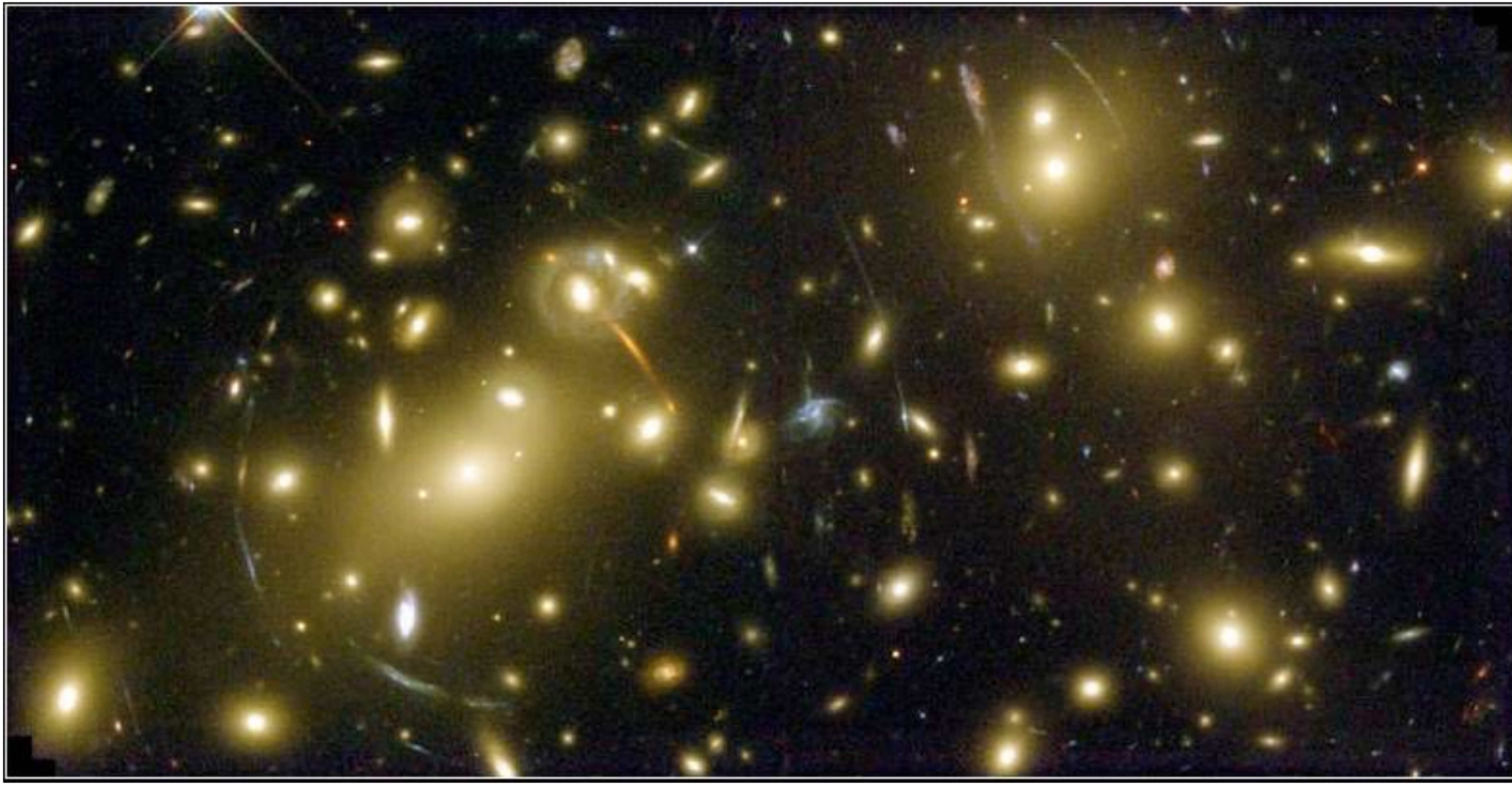




BUT - Orbital timescale for TDGs longer than the age of the merger that created them, so assumption of dynamical equilibrium is dubious. Weird.

TDGs are an important test, but the jury is still out.

Galaxy Clusters



Gravitational lensing in a galaxy cluster