Scaling relations

Local Group Timing
Too Big To Fail
Groups & Clusters

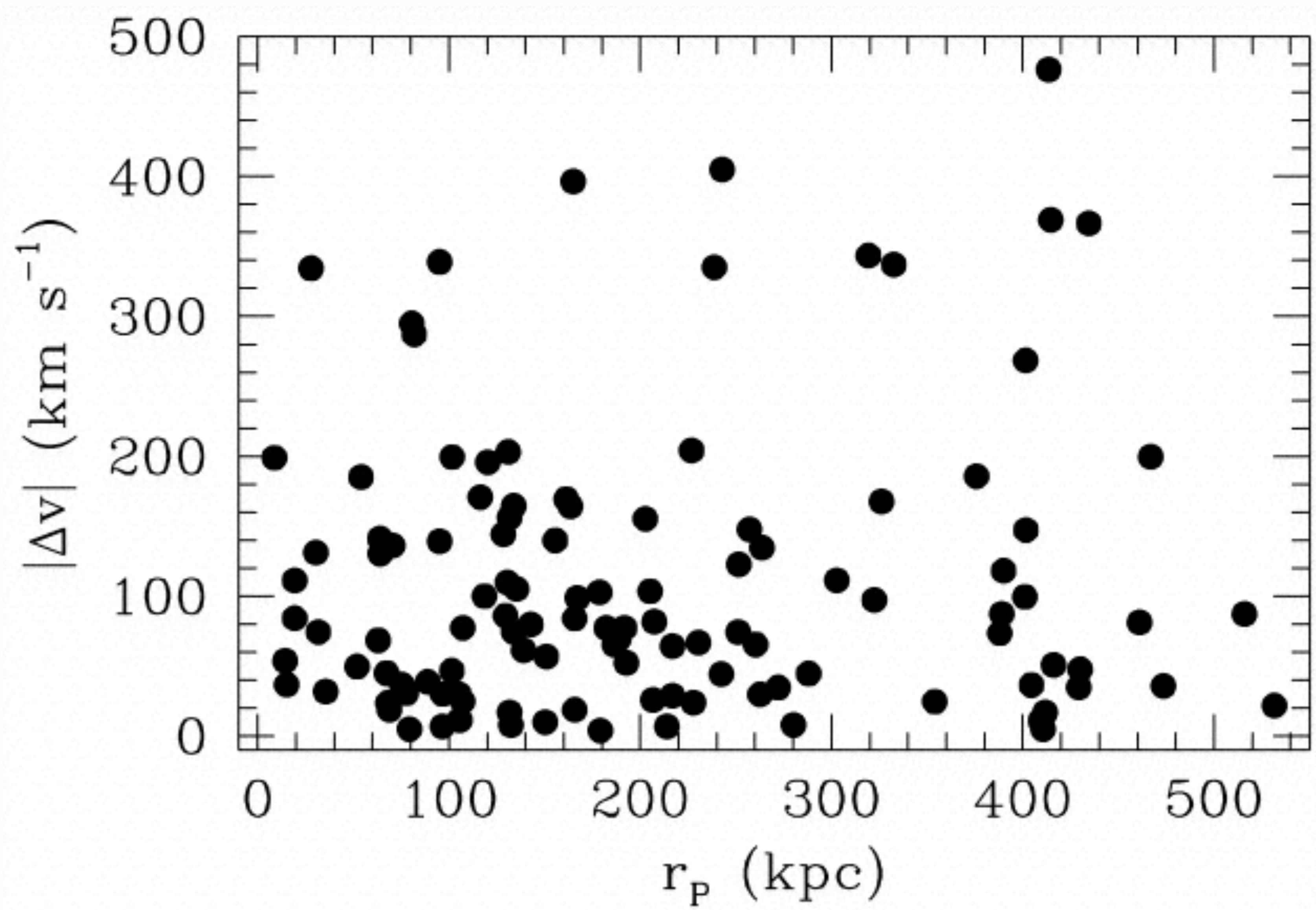
homework due next time

Timing Problem

How long does it take for the Milky Way and Andromeda to collide?

Satellite Galaxies (statistical) (Zaritsky et al. 1994; 1997)

Projected line-of-sight velocities between satellite galaxy candidates and host primaries. Must make an uncertain correction for interlopers - galaxies projected along the line of sight that are not genuine satellites.

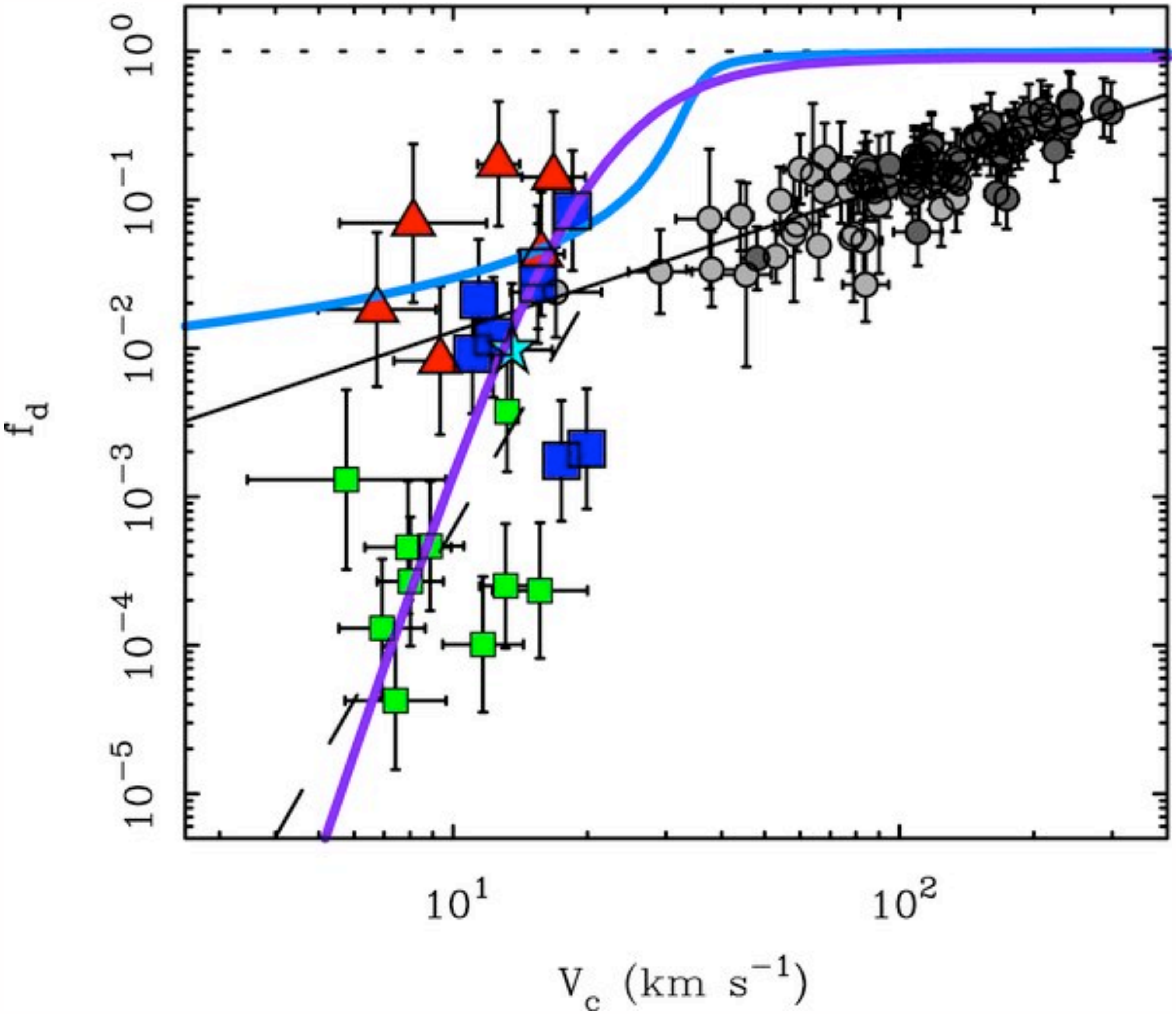


$$\langle M \rangle = \frac{48}{\pi} \langle V_c^2 \rangle \langle \frac{r_p |\Delta v|^2}{2 G V_c^2} \rangle$$

No clear end to halos of L* galaxies for 100s of kpc. Can be fit with either pISO or NFW density profile (flat V or slowly declining).

Too Big to Fail?

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

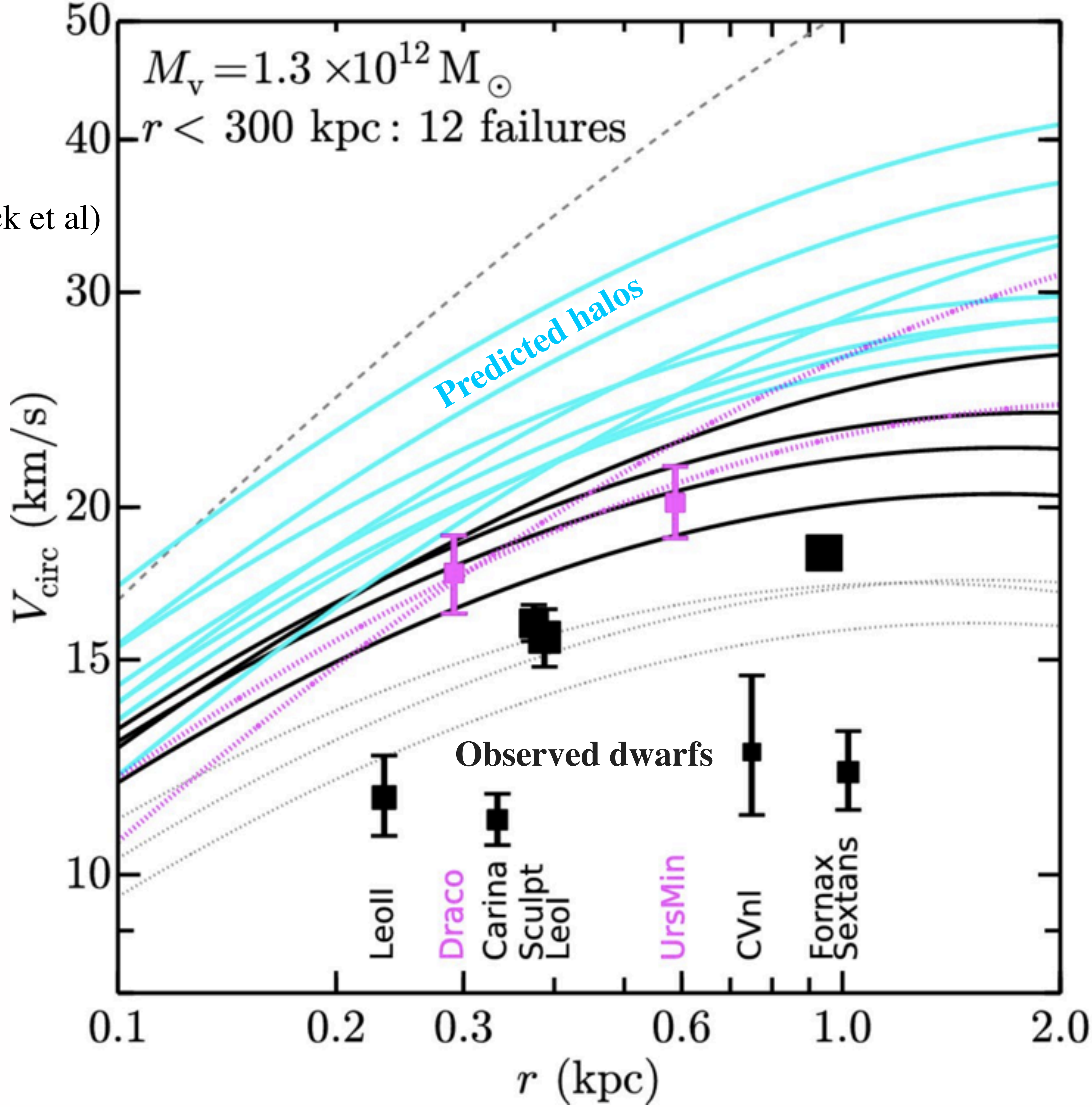


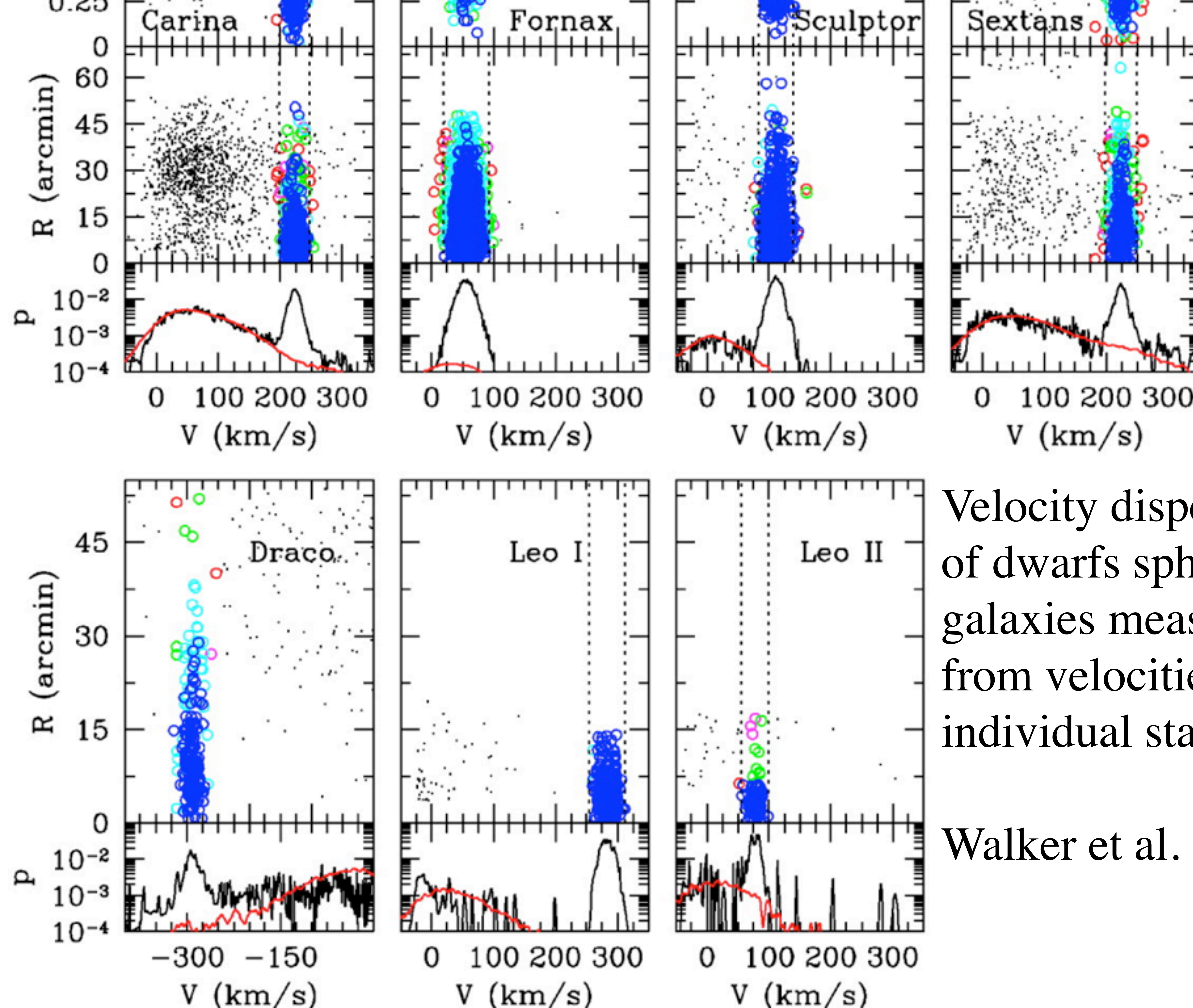
e.g., Reionization models illustrated here are good for explaining the smallest galaxies, but not ~40 km/s halos, which are too big to fail.

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?



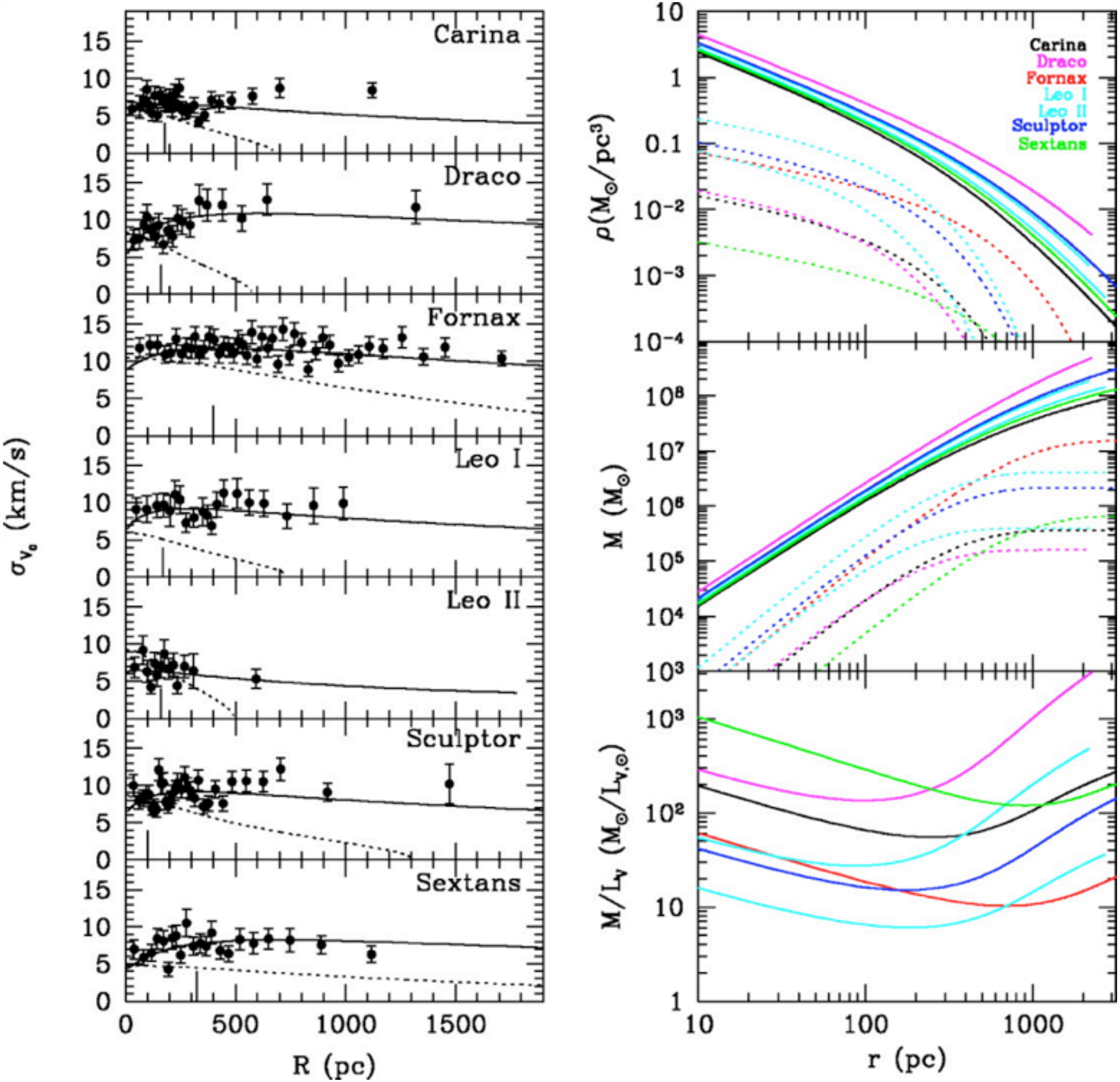


Velocity dispersions of dwarfs spheroidal galaxies measured from velocities of individual stars.

Walker et al. (2007)

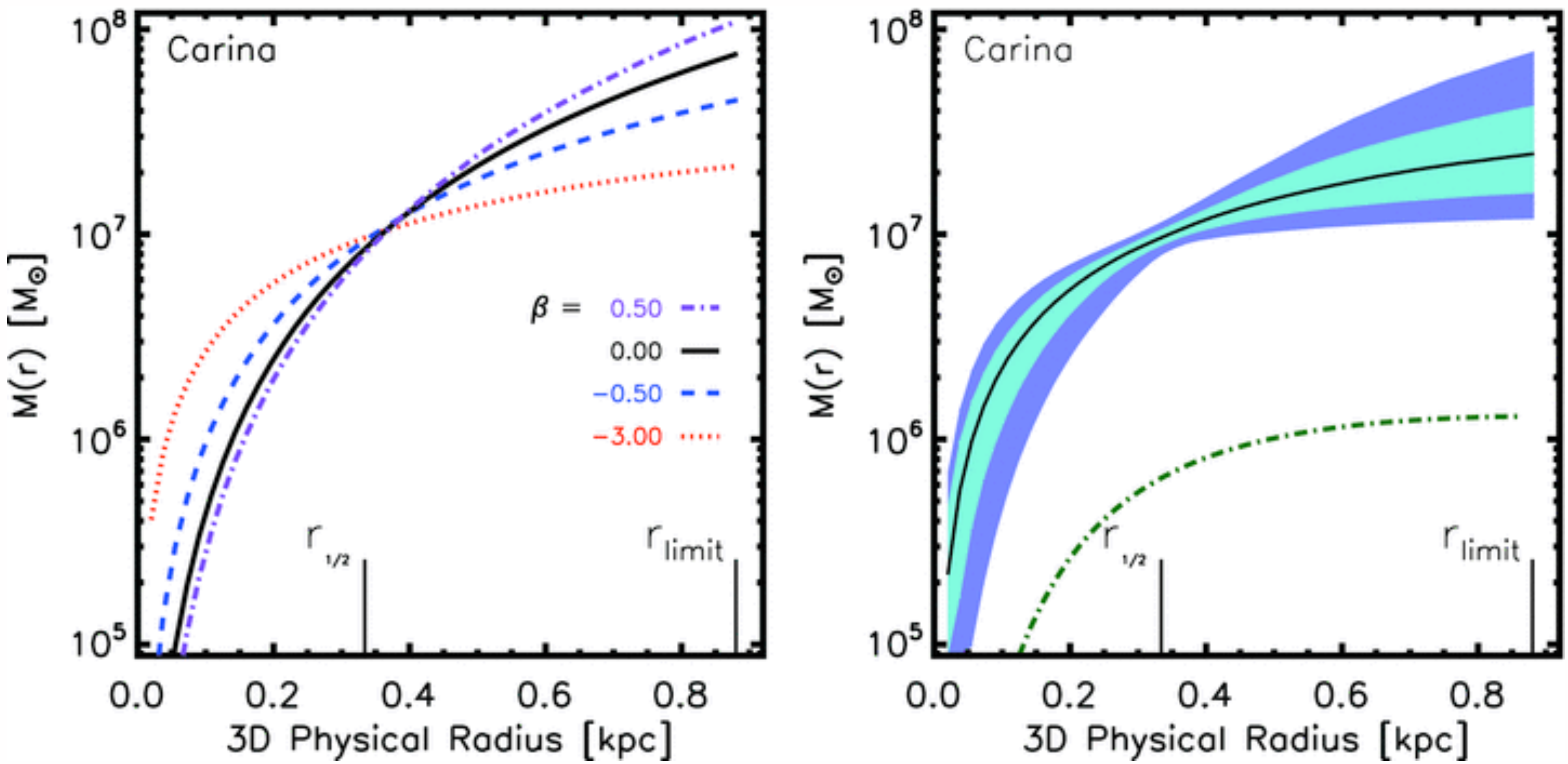
Velocity dispersion profiles of dwarfs spheroidal galaxies approximately flat.

Walker et al. (2007)



The "best" place to measure the velocity dispersion is at the half-light radius, as this minimizes the uncertaintes due to anisotropy.

Wolf et al. (2010)



$$M(r) = \frac{r\sigma_r^2}{G}(\gamma_* + \gamma_\sigma - 2\beta)$$

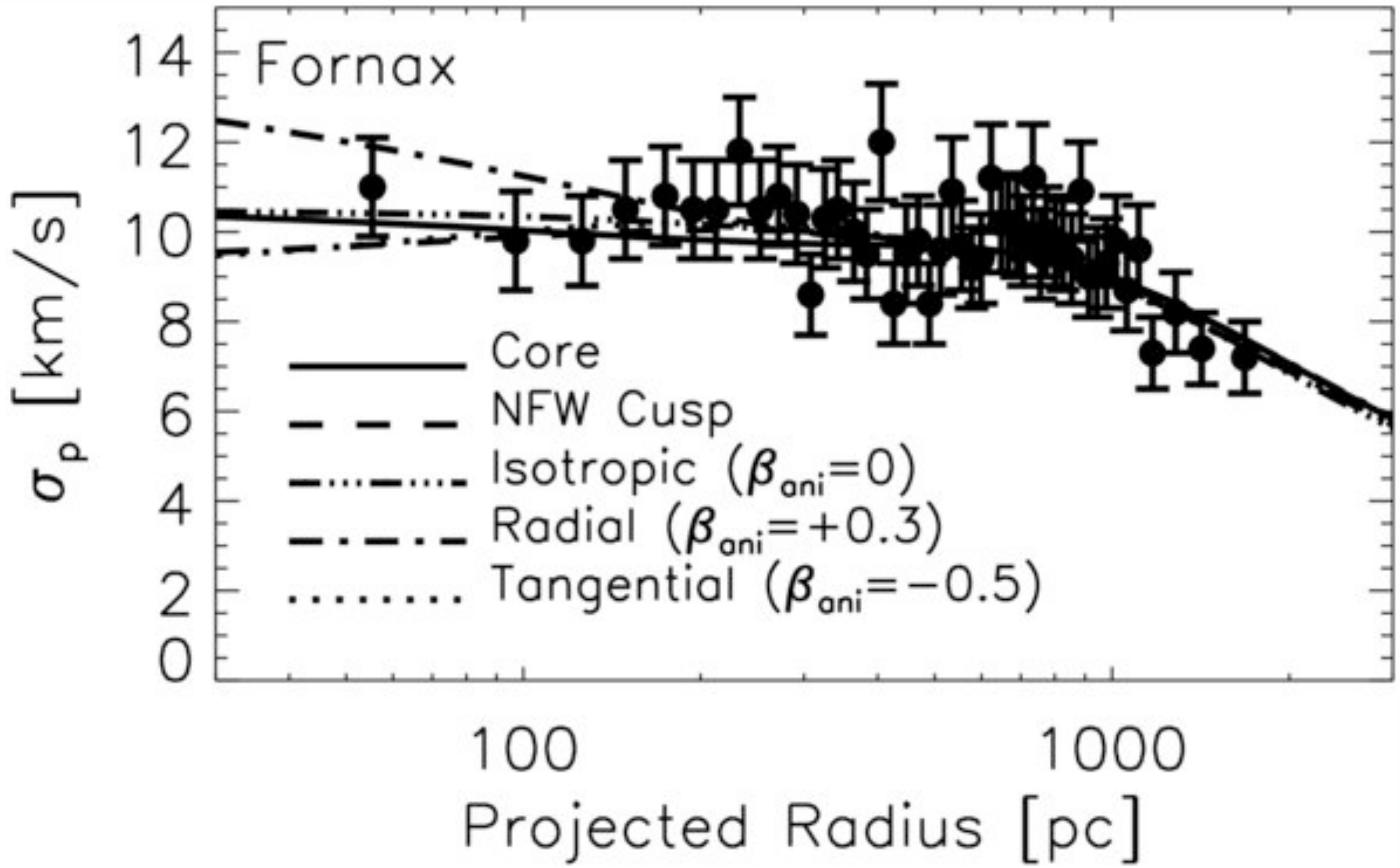
Walker & Penarrubia (2011) find that dSph galaxies suffer the same cusp-core problem as found in rotating low surface brightness galaxies

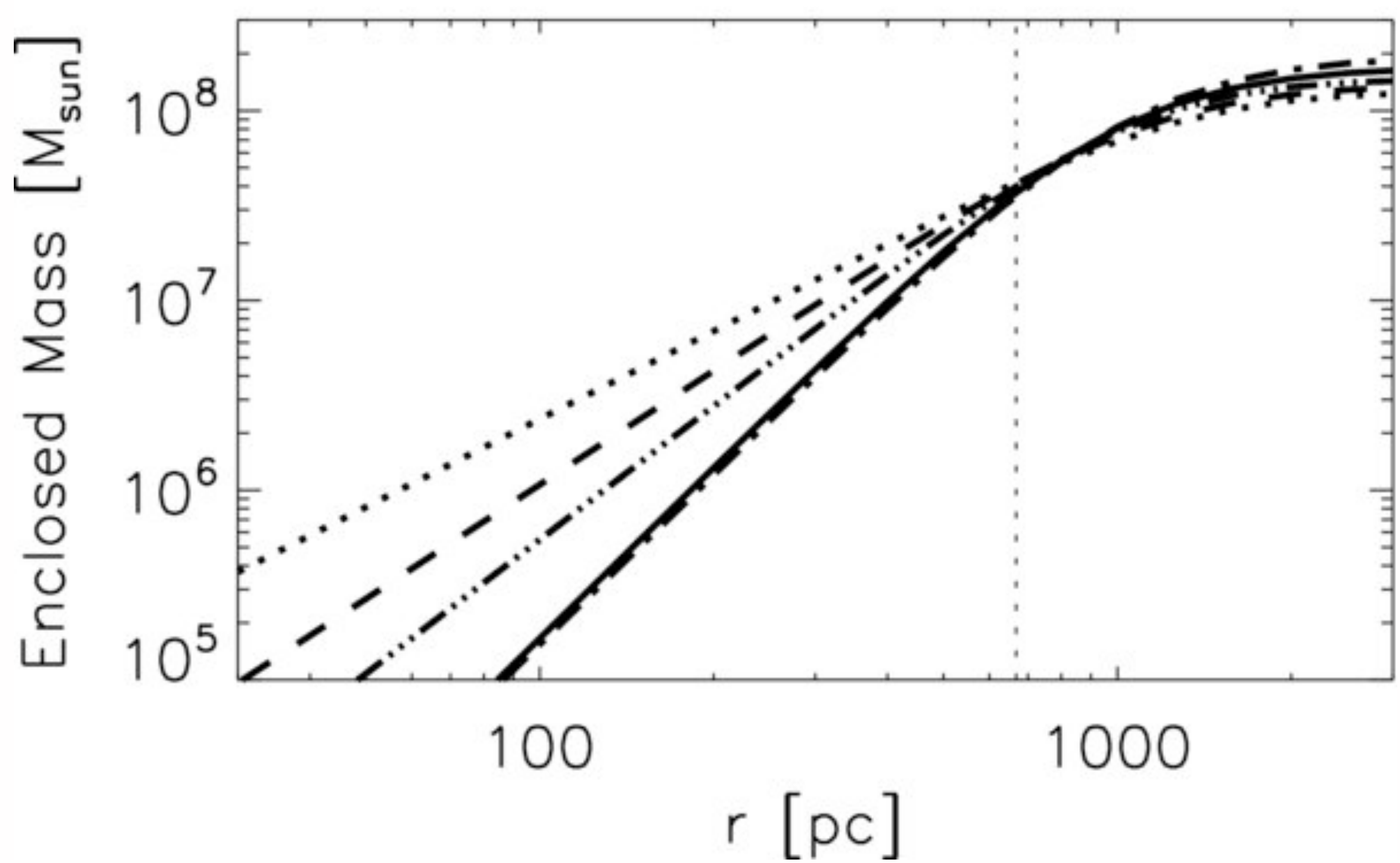
$$\rho \sim r^{-\gamma}$$

$\gamma = 0.39$ Fornax

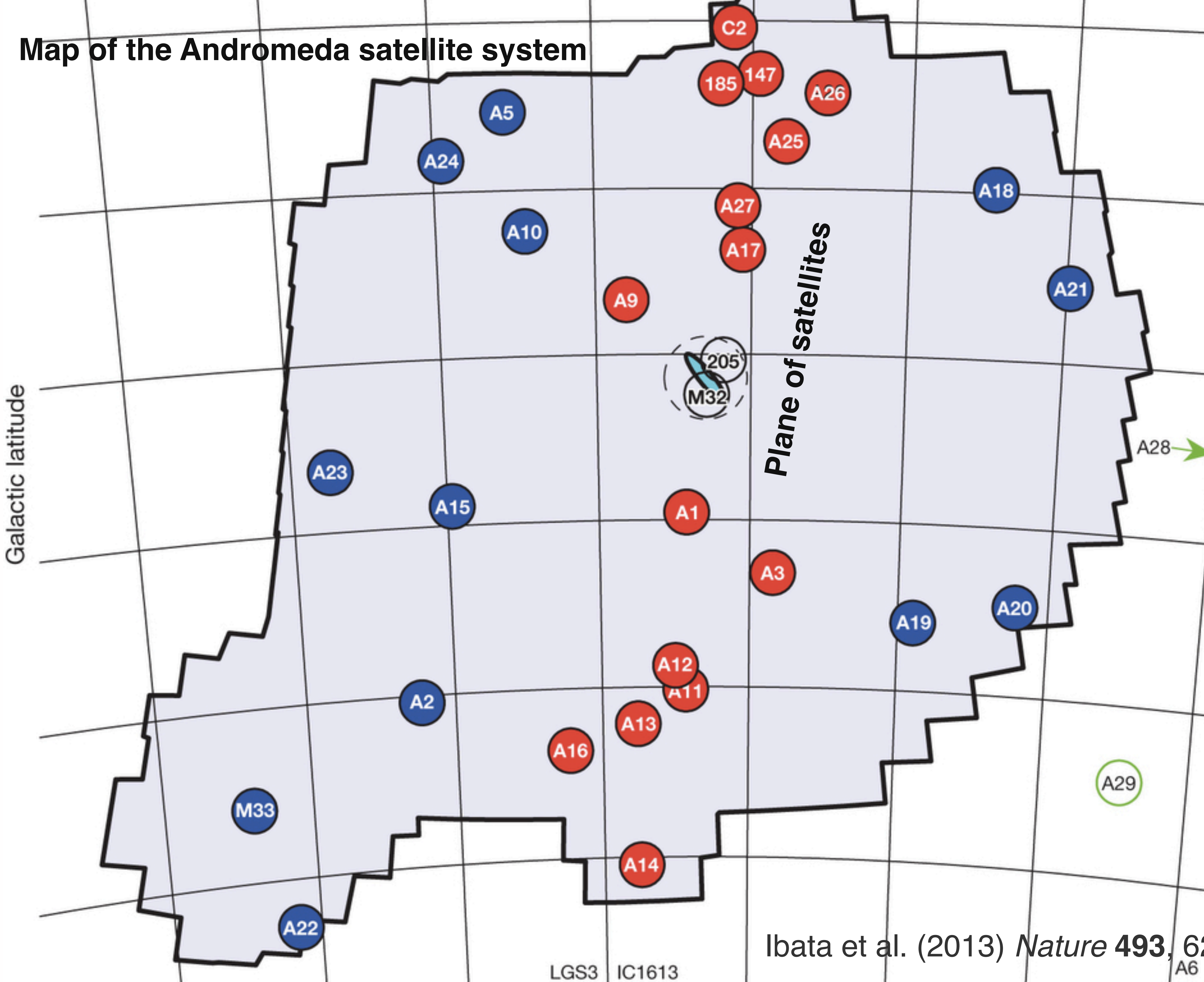
$\gamma = 0.05$ Sculptor

$$\left[\begin{array}{ll} \gamma = 1 & \text{cusp} \\ \gamma = 0 & \text{core} \end{array}\right]$$





Map of the Andromeda satellite system



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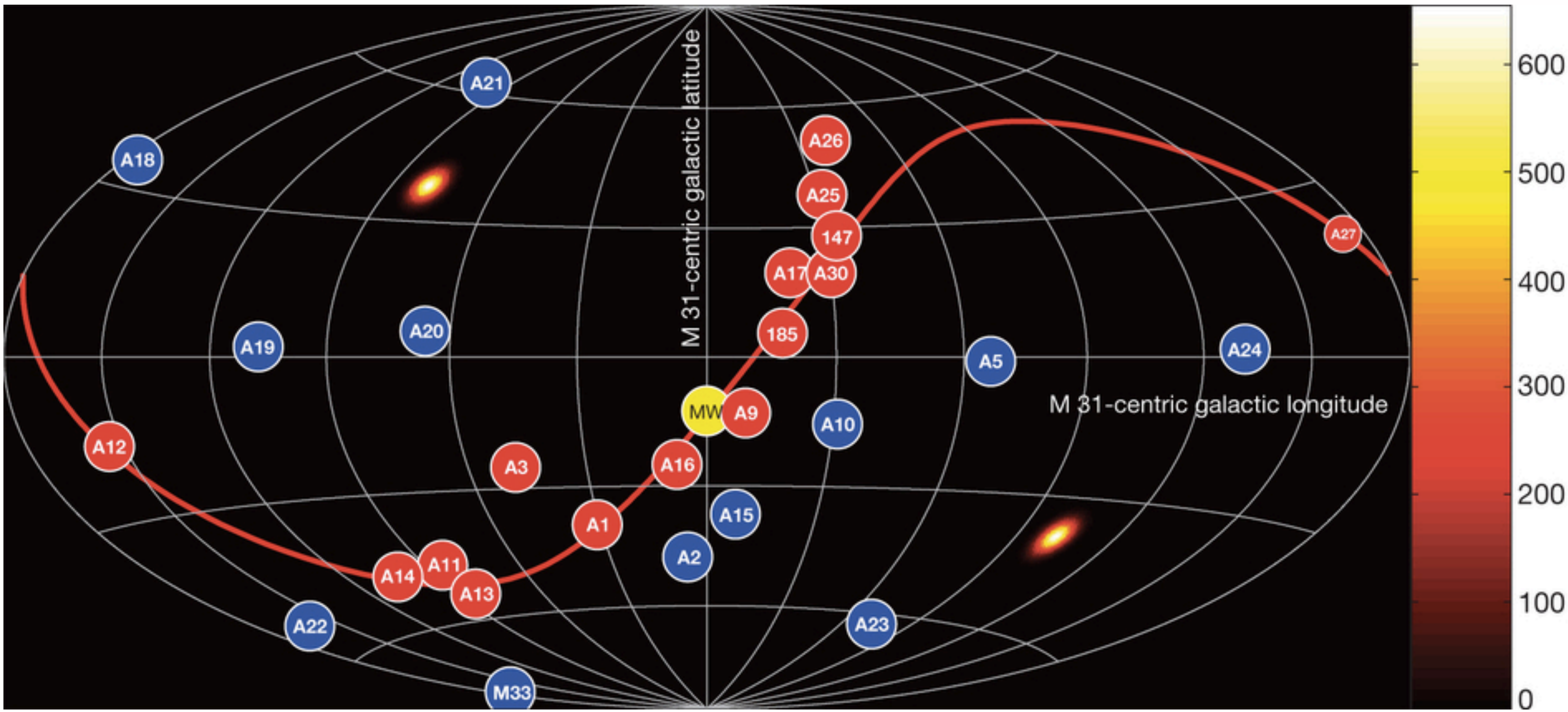
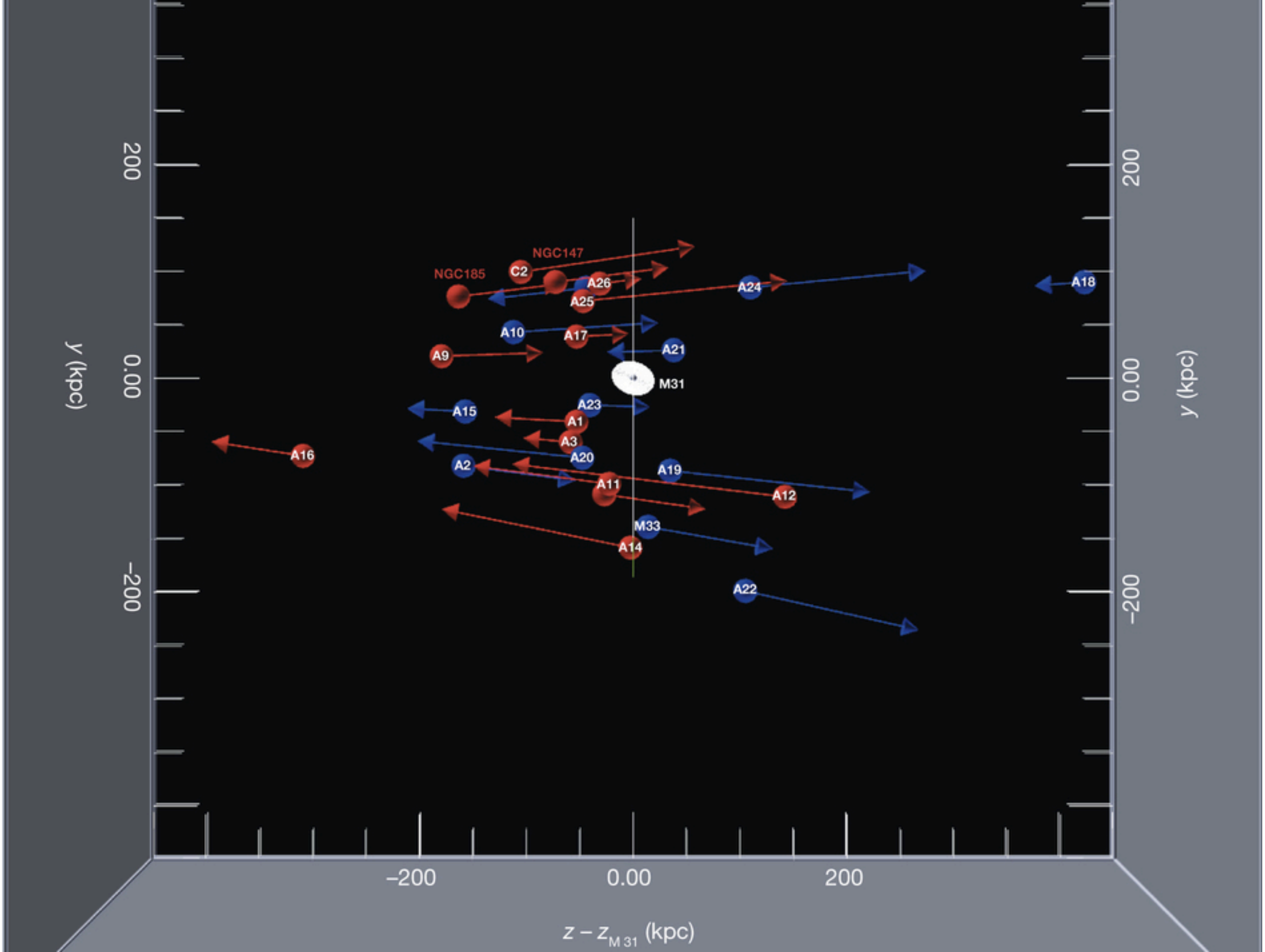
Satellite galaxy positions as viewed from Andromeda



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

The planar, rotating structure.



Dwarf spheroidals 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 exected 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 funciton problem (flat rather than steep fainte end slope).