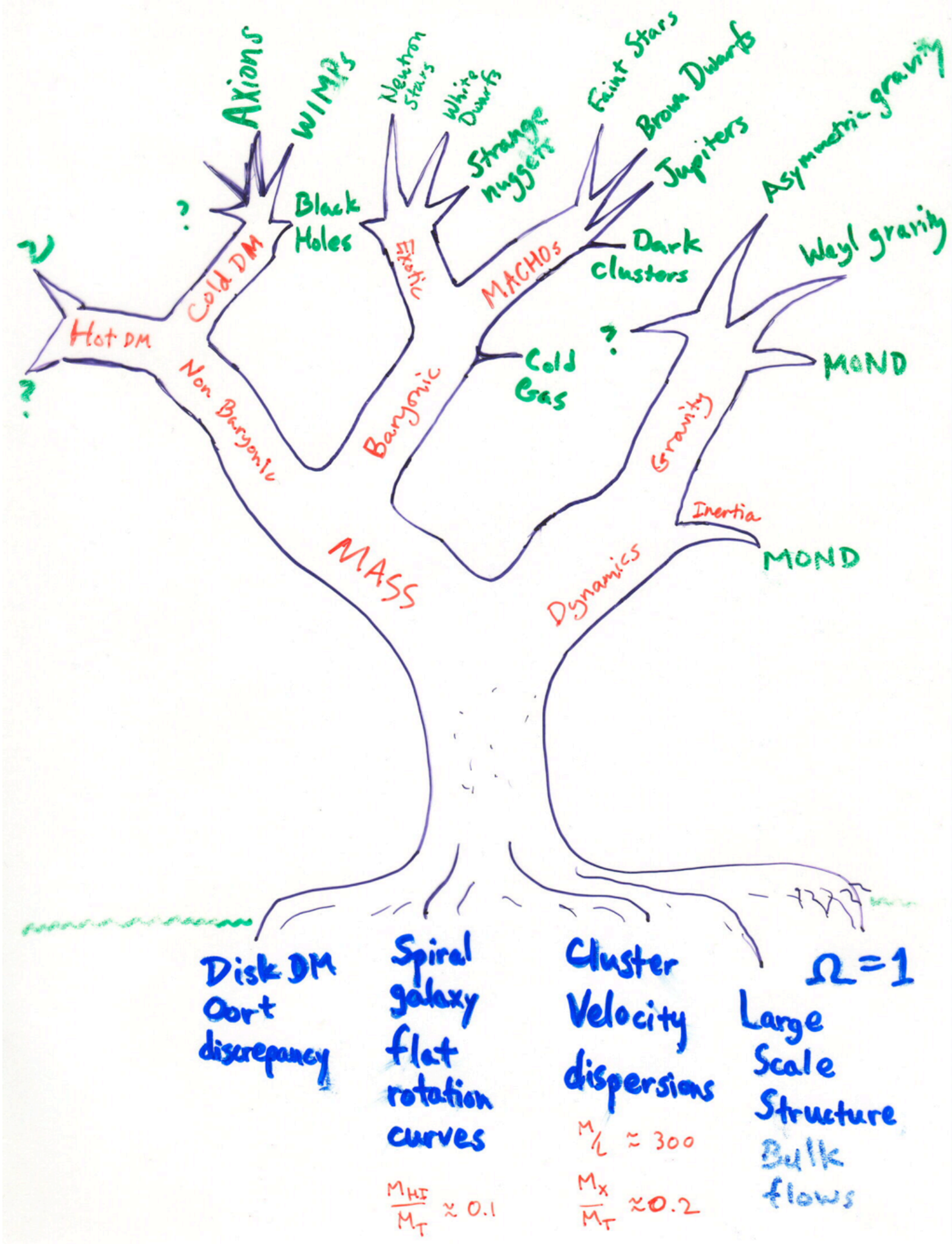
Dark Matter

ASTR 333/433

TODAY

Feedback
Overcooling Problem
Missing Satellites

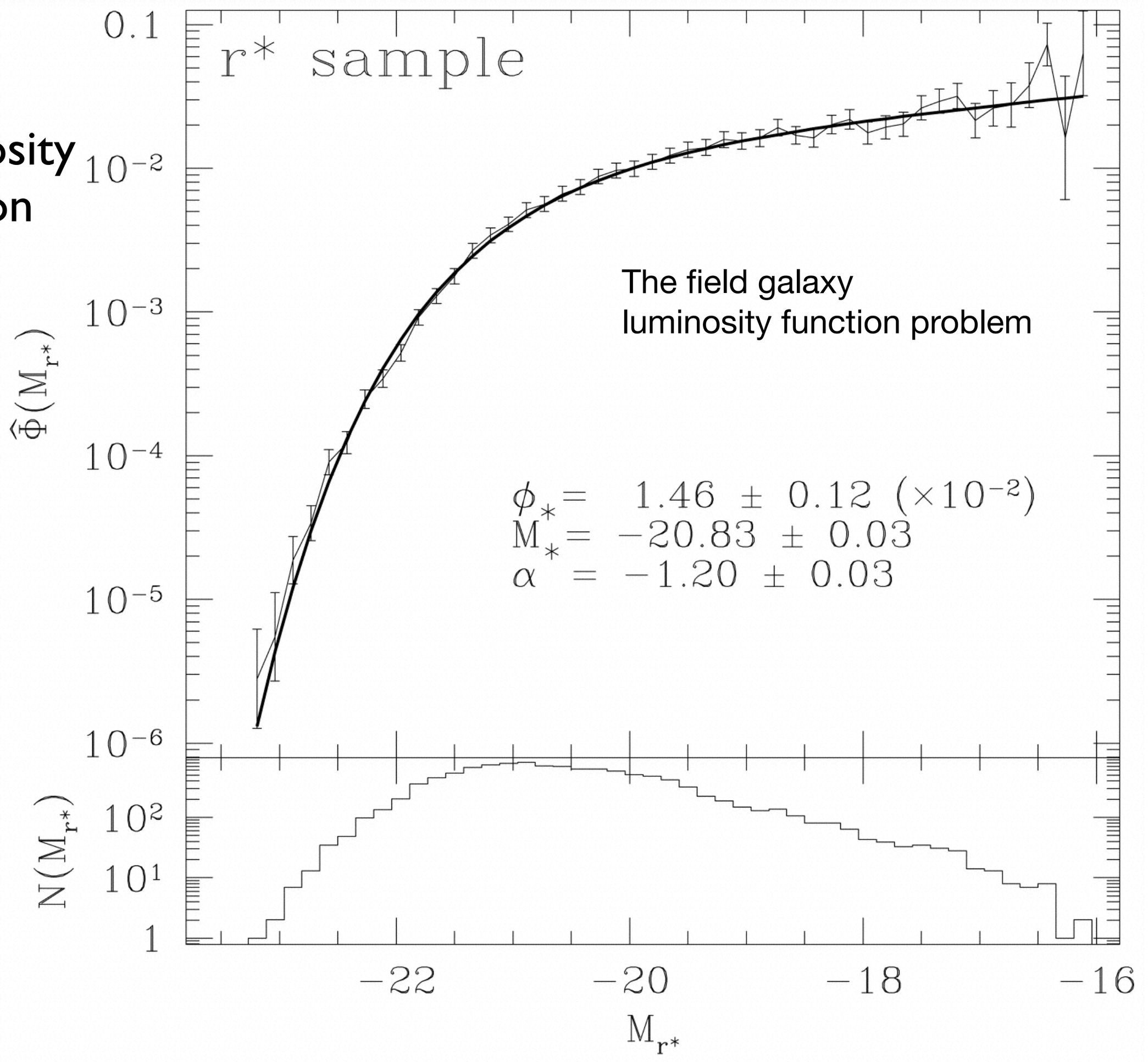


Generic CDM problem

- Too much mass at small radii
  - Cusp-core problem
  - Massive bulges & near-maximal disks (bright galaxies)
- Missing Satellites
  - too few satellites around bright galaxies
  - Too Big to Fail
  - overcooling problem in field

Generic prescription: Feedback

SDSS r-band luminosity function



Baryonic Mass Function (Read & Trentham 2005)

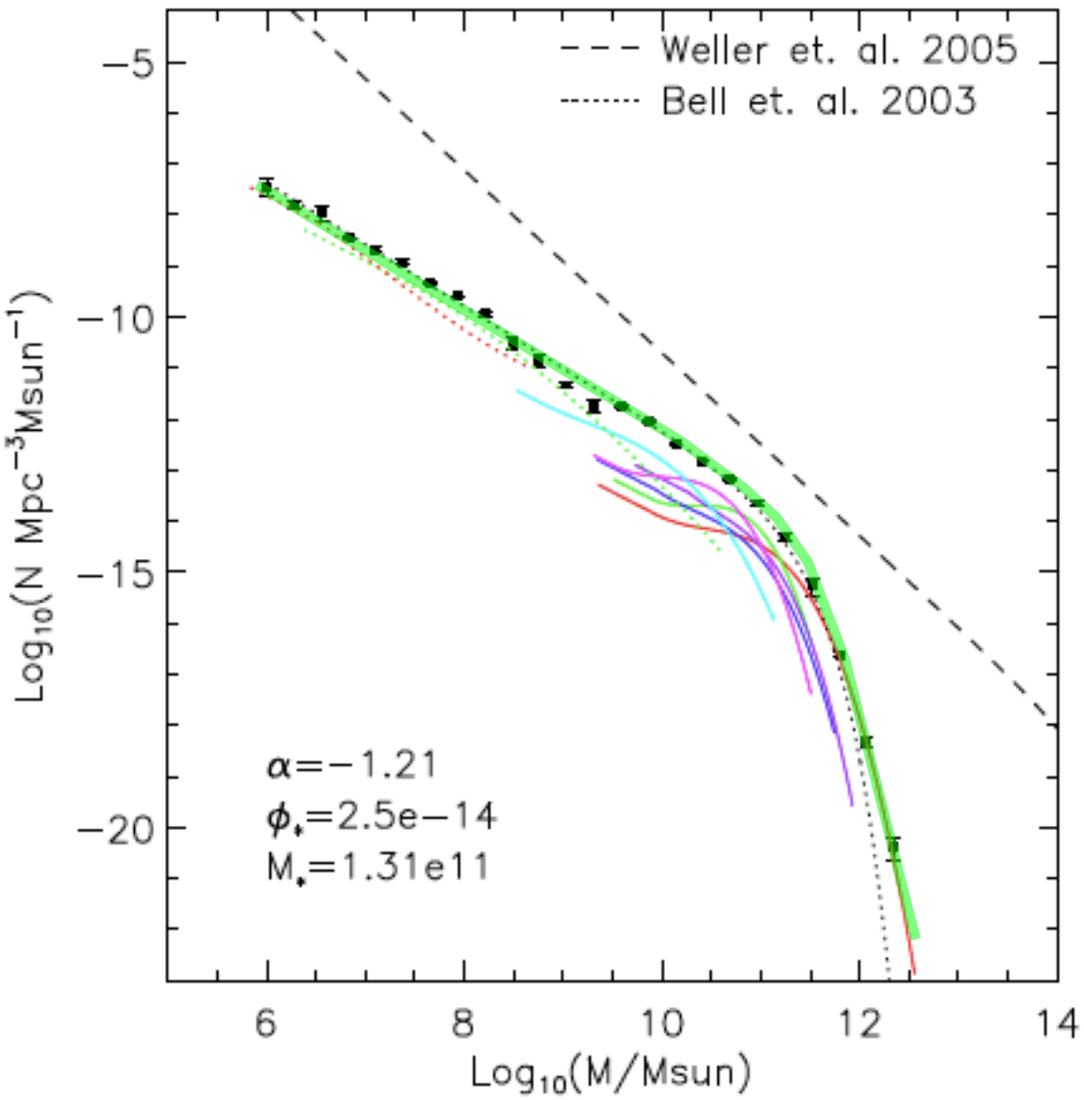
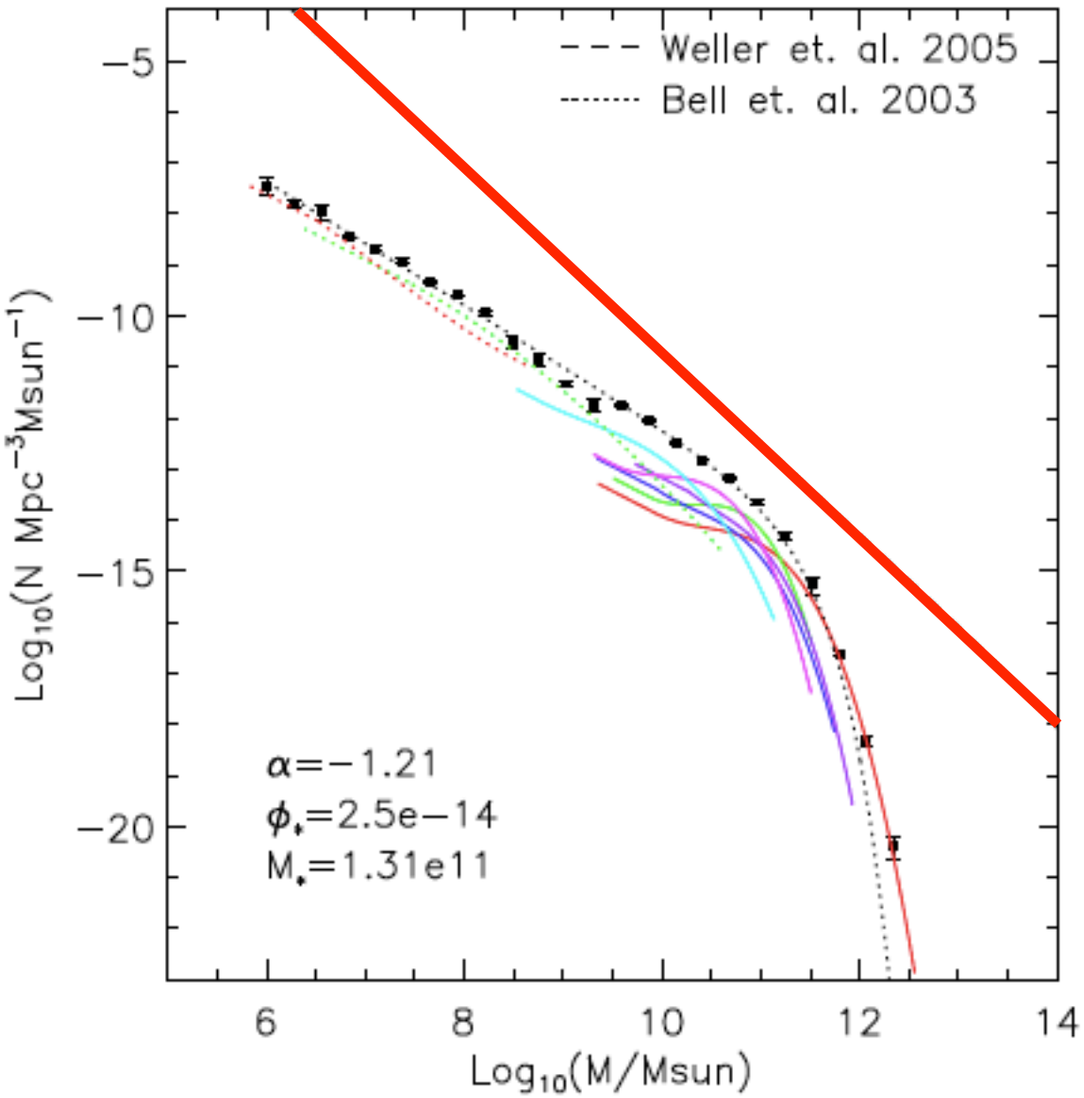


Figure 4. The field galaxy baryonic mass function. The data points are for all galaxies, while the lines show spine fits by Hubble Type. The lines are as in Figure 2. The CDM mass spectrum from the numerical simulations of Weller et al. (2004) is also shown. Overlaid are parameters for a Schechter fit to the total mass function.

The **missing satellite problem** or more generally the **over-cooling problem** - a mismatch between the predicted halo mass function and the field galaxy luminosity function

observed galaxies

Baryonic Mass Function
(Read & Trentham 2005)



CDM halo
mass function

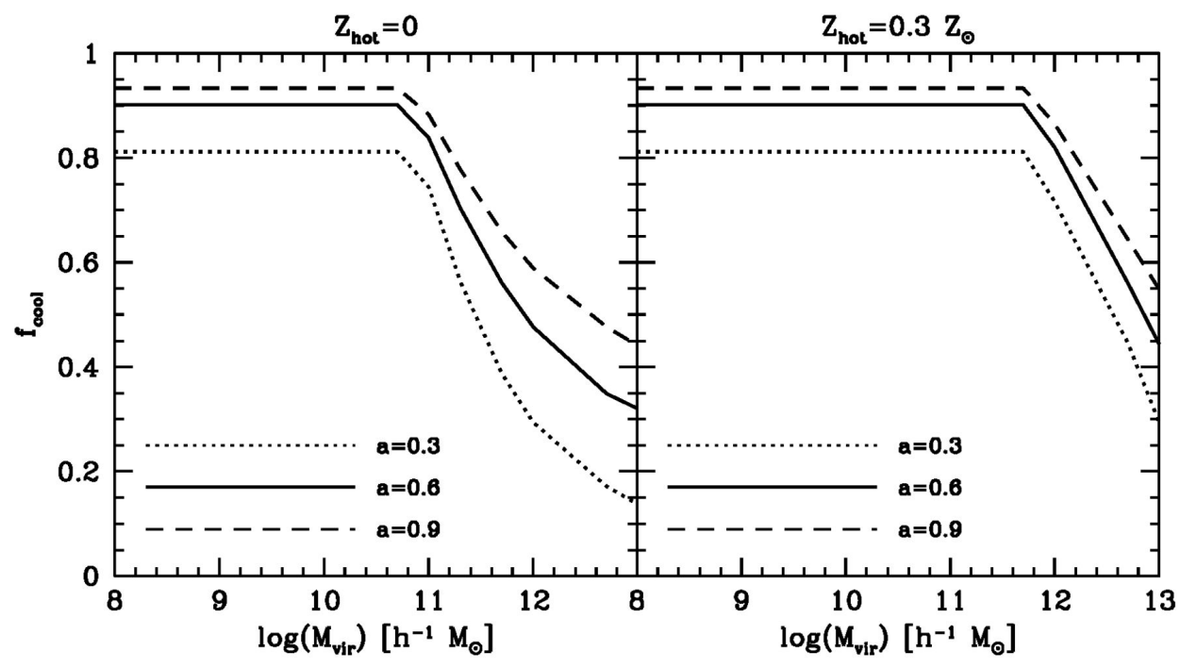
$\alpha = -1.9$

Figure 4. The field galaxy baryonic mass function. The data points are for all galaxies, while the lines show spine fits by Hubble Type. The lines are as in Figure 2. The CDM mass spectrum from the numerical simulations of Weller et al. (2004) is also shown. Overlaid are parameters for a Schechter fit to the total mass function.

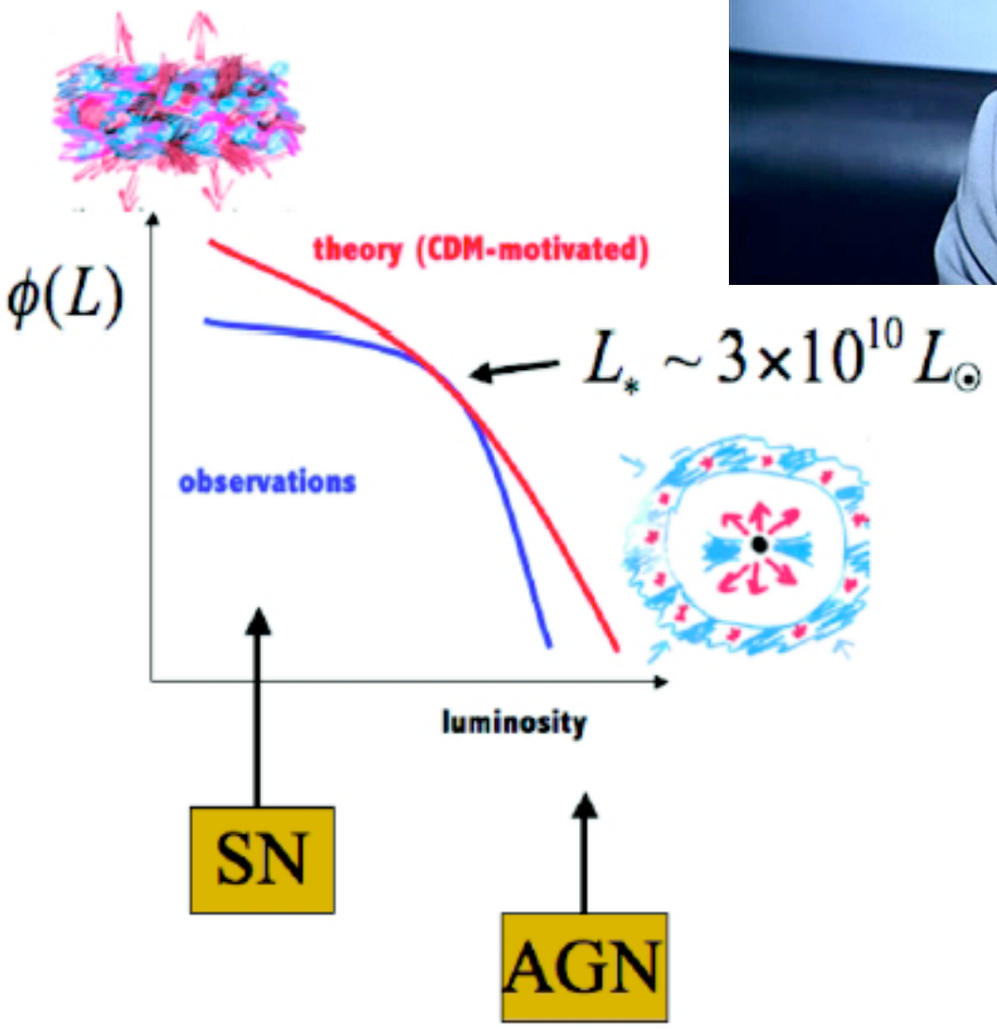
Overcooling problem

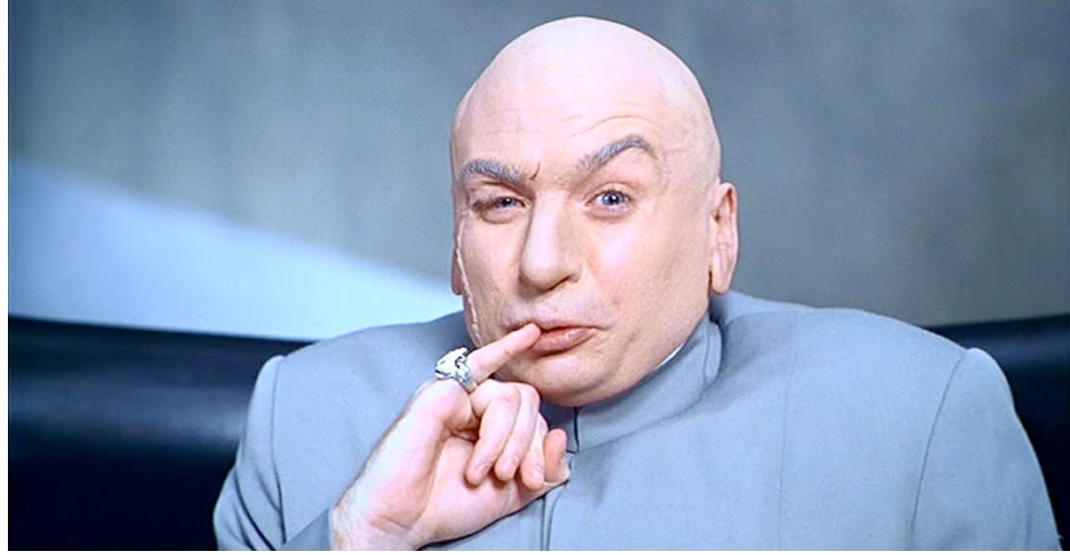
- Baryons in low (galaxy) mass halos have time to cool
  - Should condense & form stars
- Fewer baryons than expected are observed

The fraction, f_{cool}, of baryonic mass inside the virial radius that has cooled and settled in present-day discs as function of the present-day virial mass. (van den Bosch 2001)



Feedback





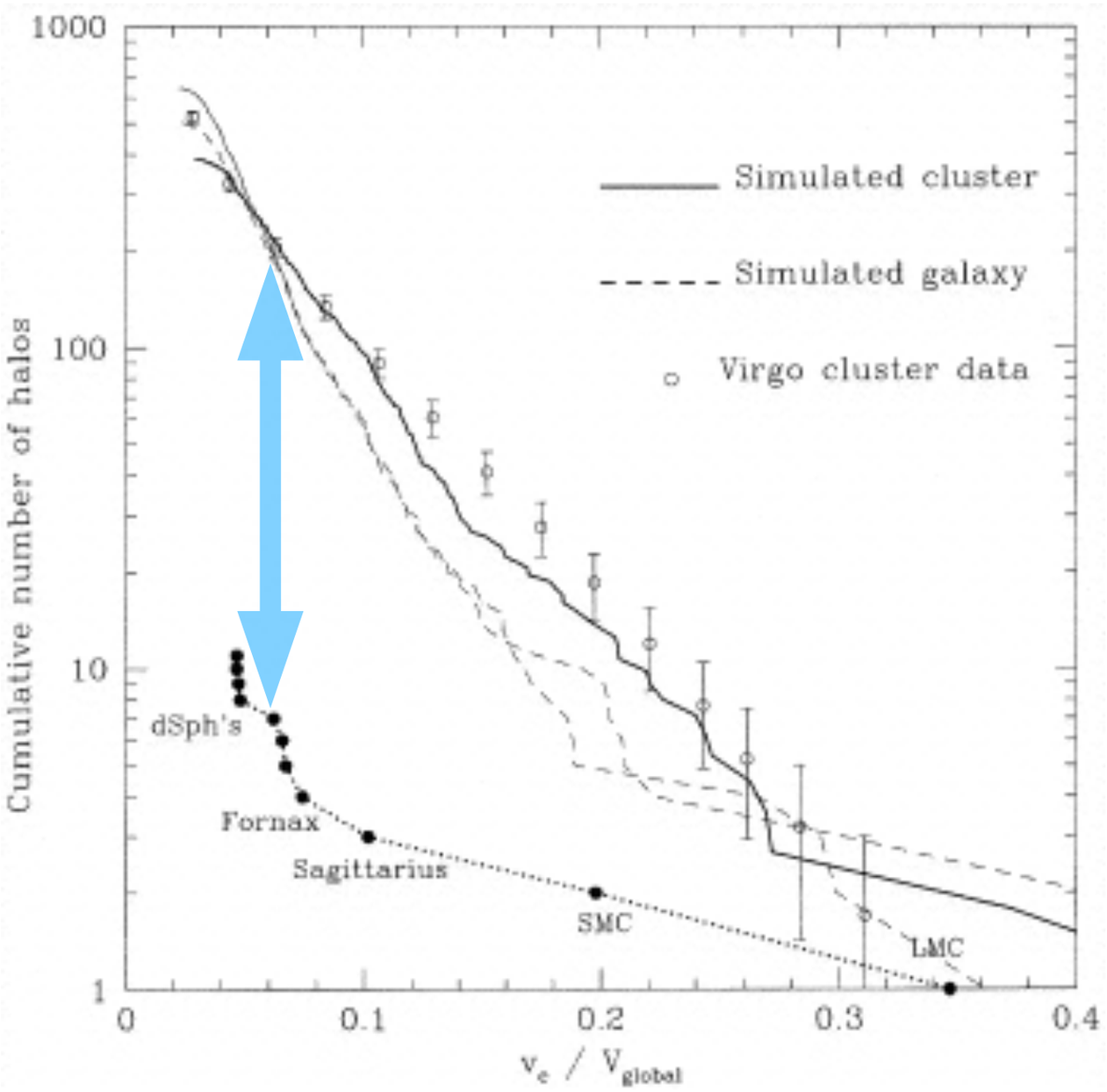
See notes for example feedback scheme (Dutton)

Basic idea: SN affect low mass halos
AGN affects high mass halos

Invoked to explain the difference between the galaxy luminosity function and the halo mass function, the cusp-core problem, and any other inconvenient observation.

Missing Satellites

e.g., Moore et al. (1999); Klypin et al. (1999)



N

V_c/V_{parent}

CDM is scale free

Dwarf spheroidals problematic for CDM in two distinct ways:

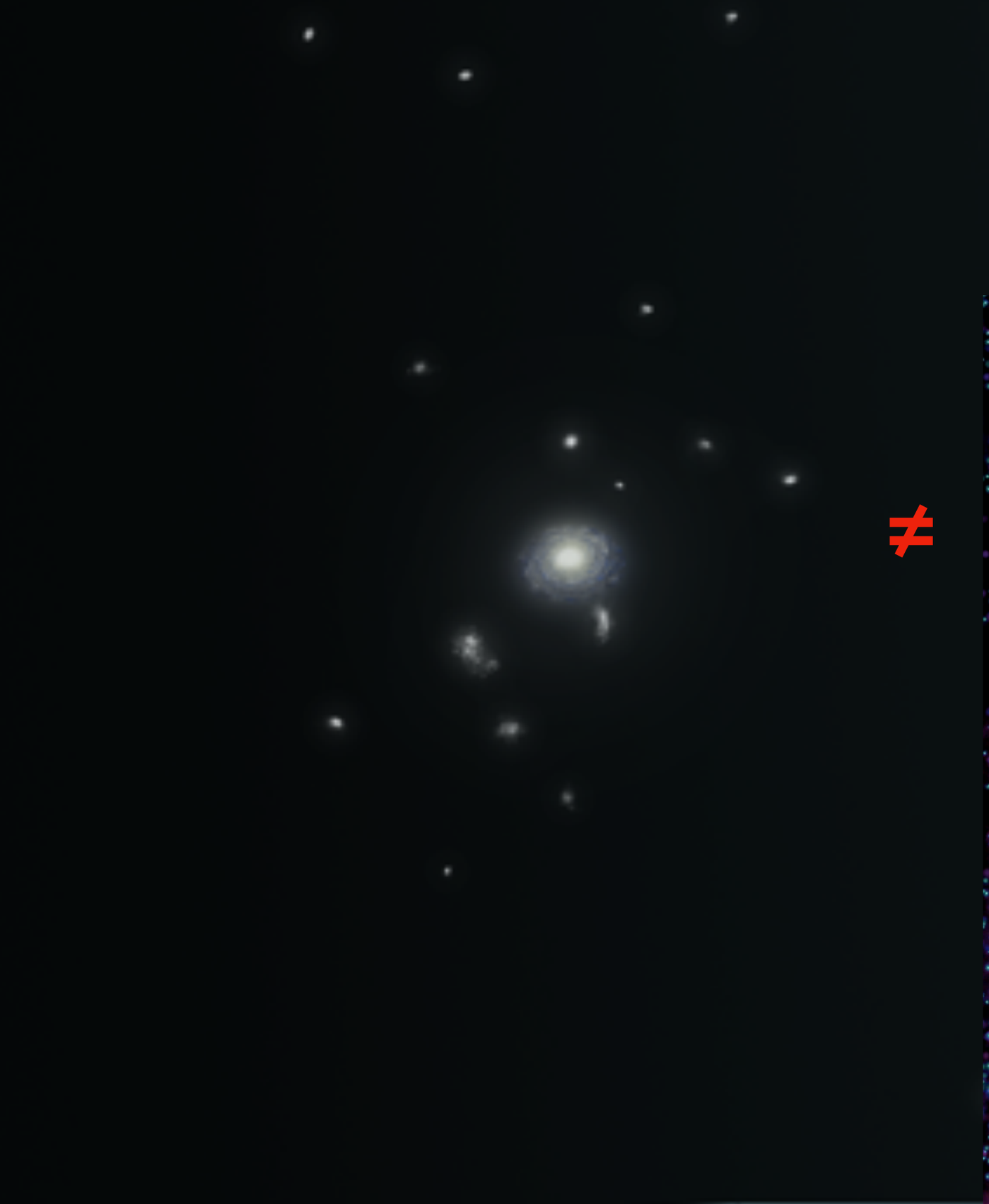
- there should be thousands of them rather than dozens (missing satellite problem)

- they have cored dark matter halos (cusp/core problem)

These are really just the same problems as before, scaled to the Local Group

The Local Group

does not look like a simulated dark matter halo

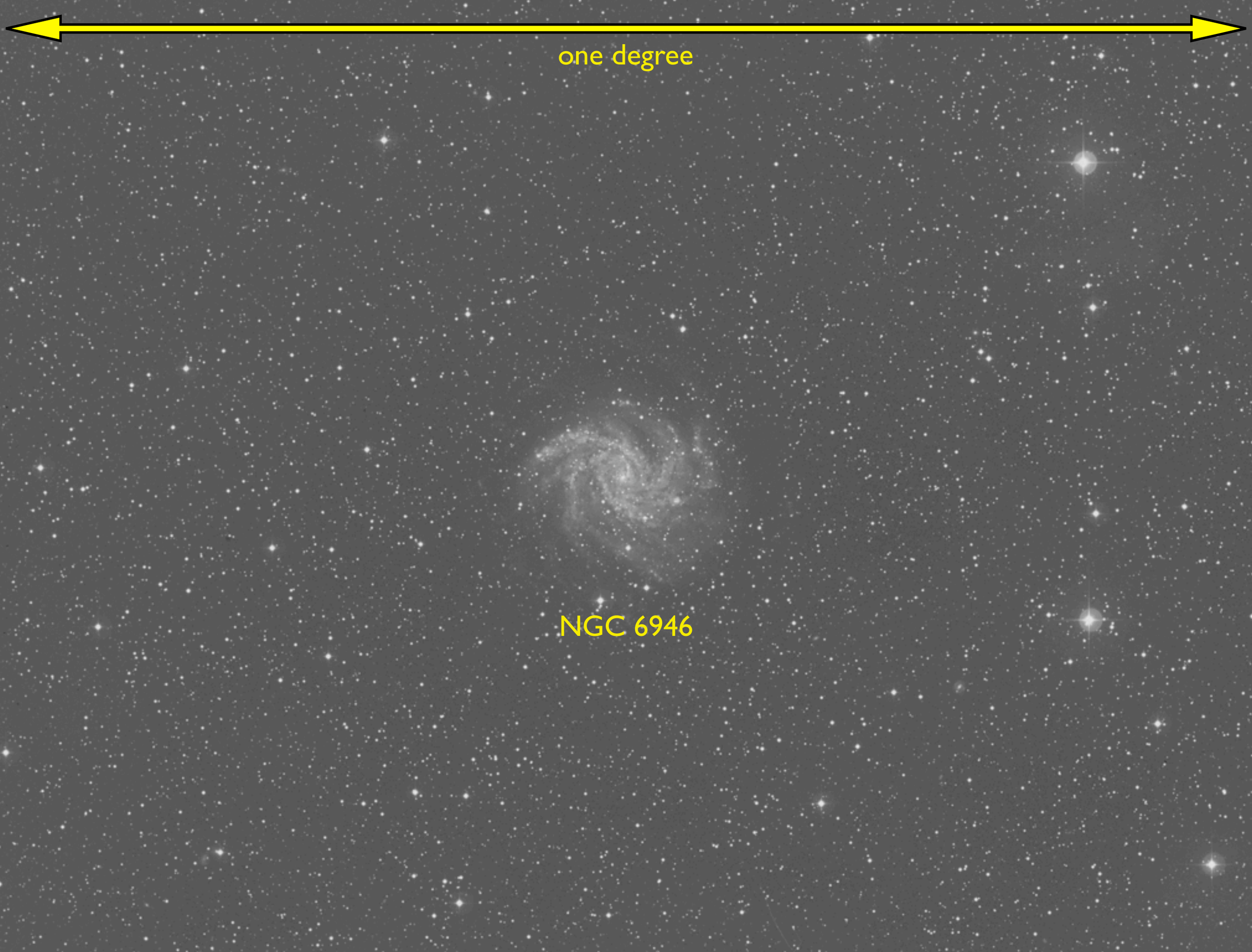


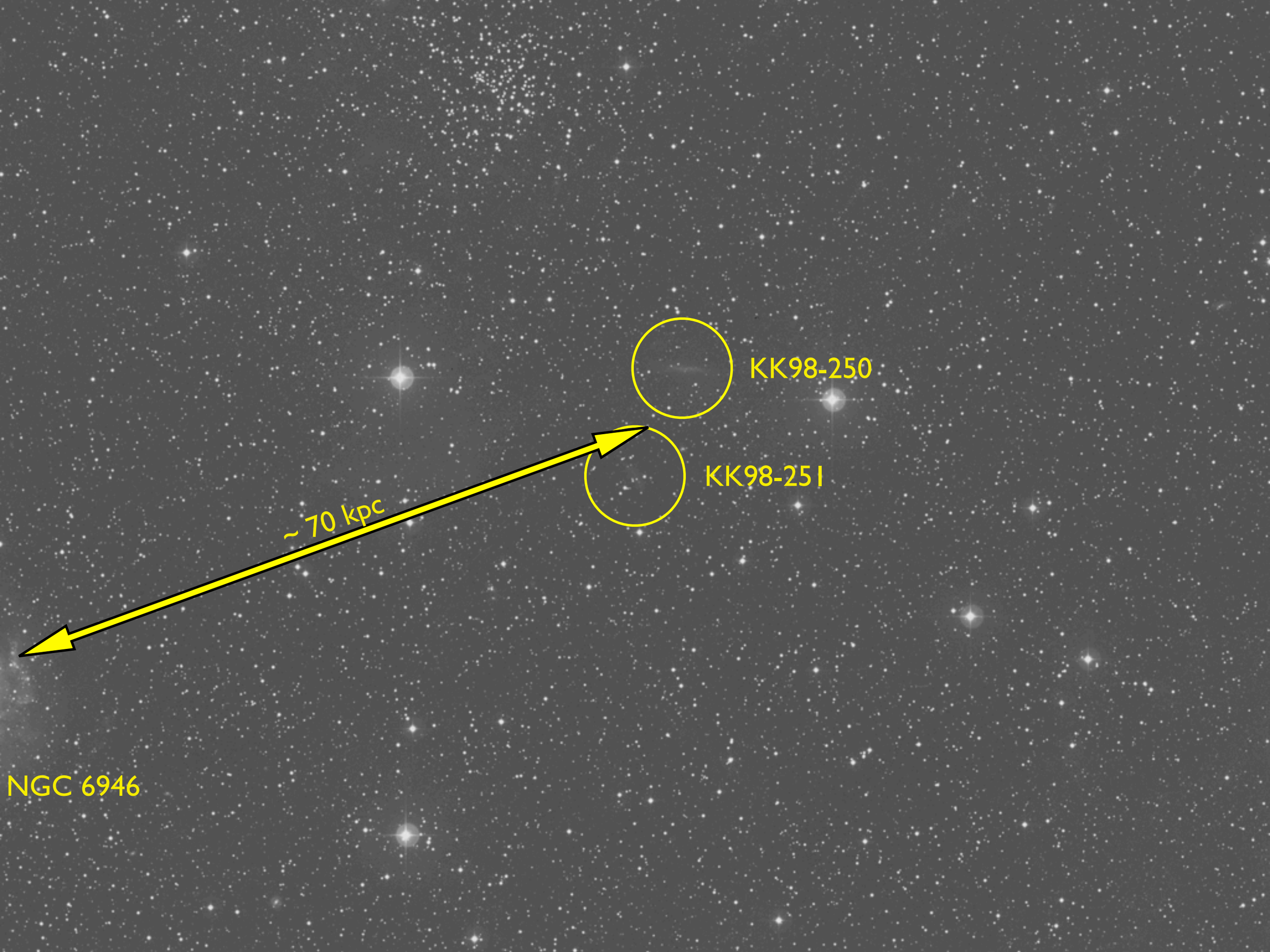
≠

THE GREAT DIVIDE

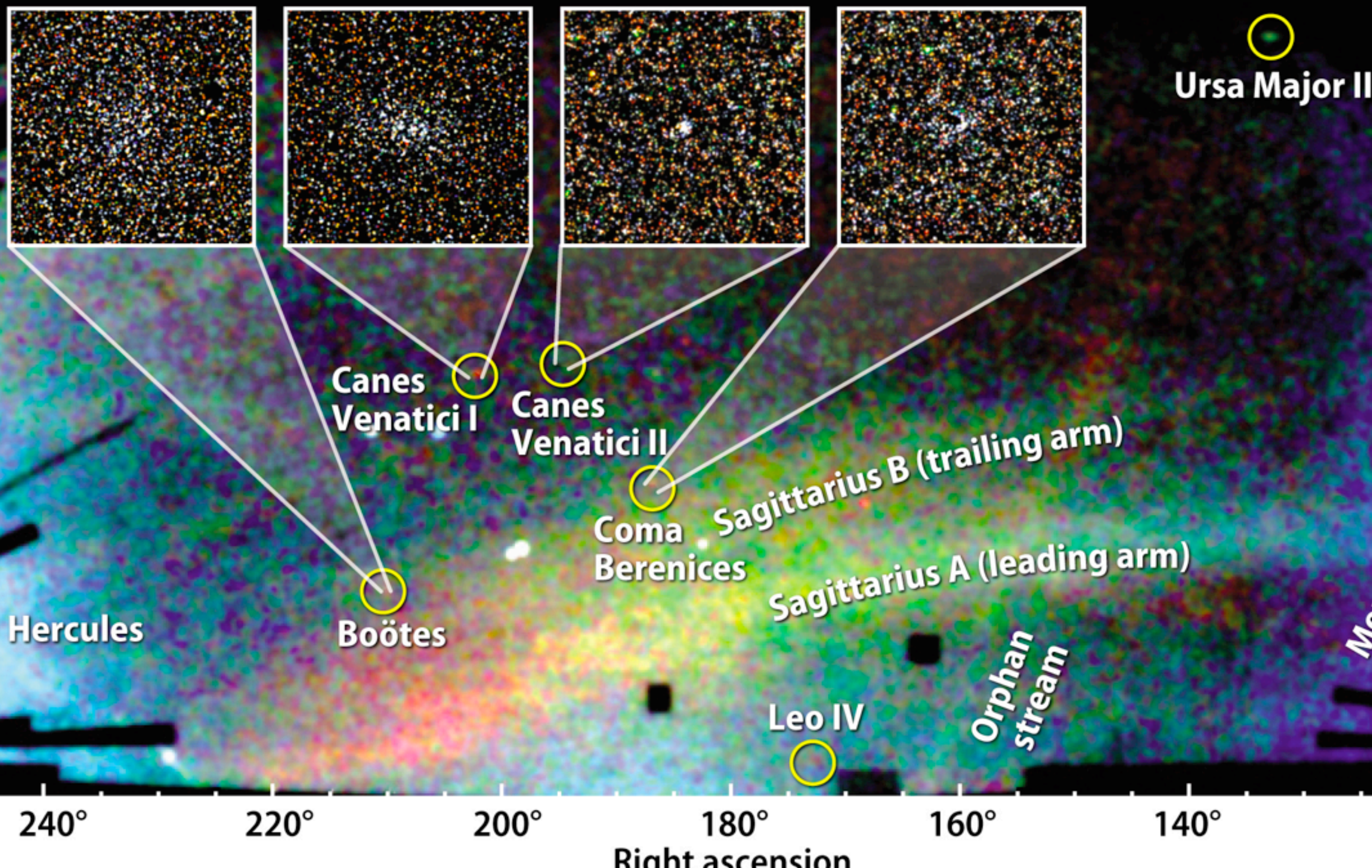
What we predict

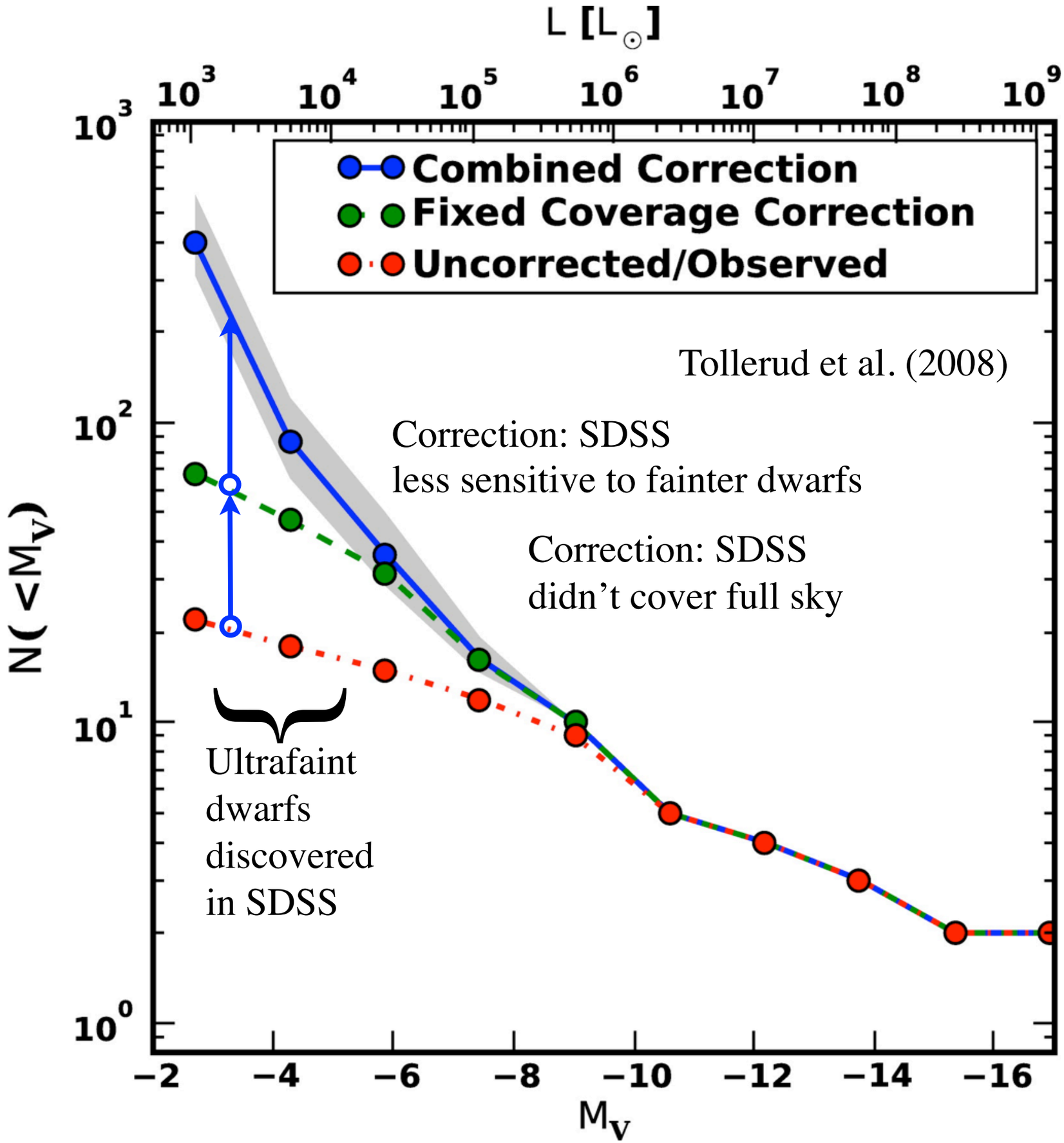
What we observe


one degree
NGC 6946

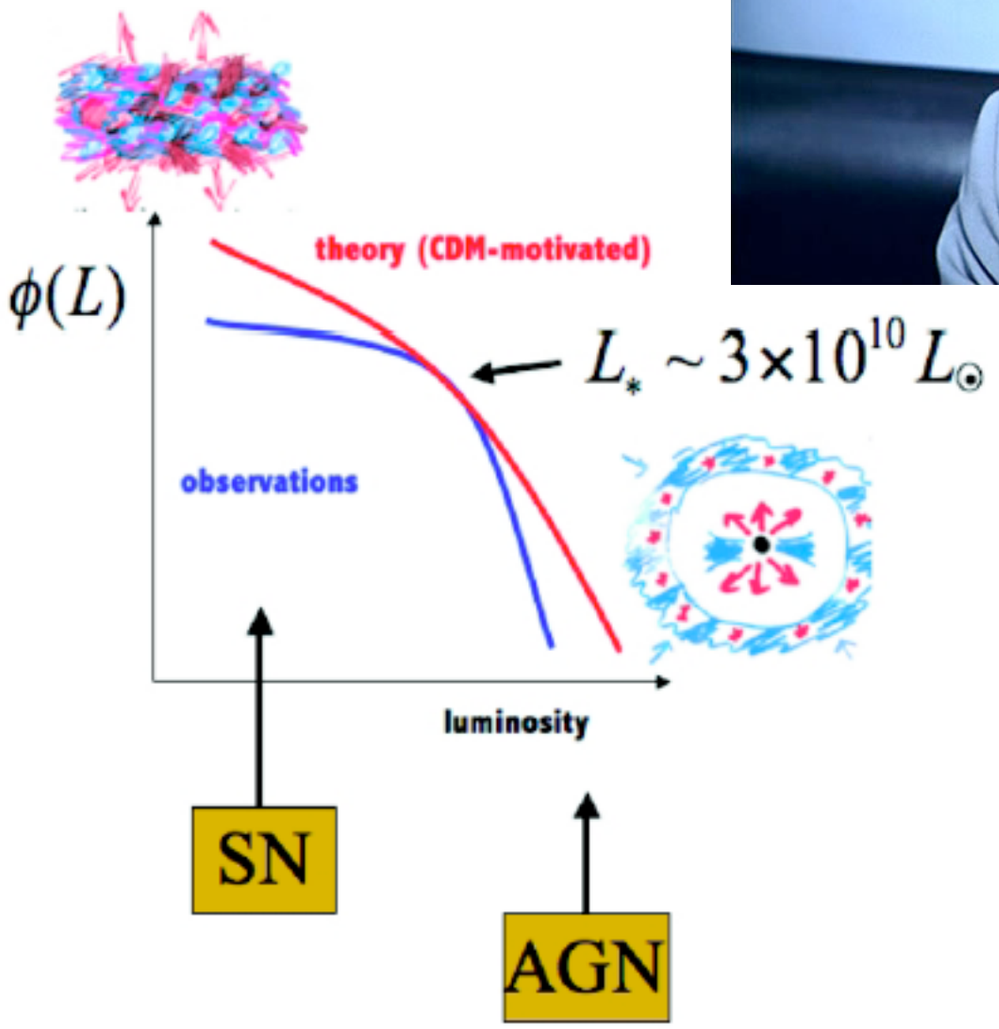

KK98-250
KK98-251
~ 70 kpc
NGC 6946

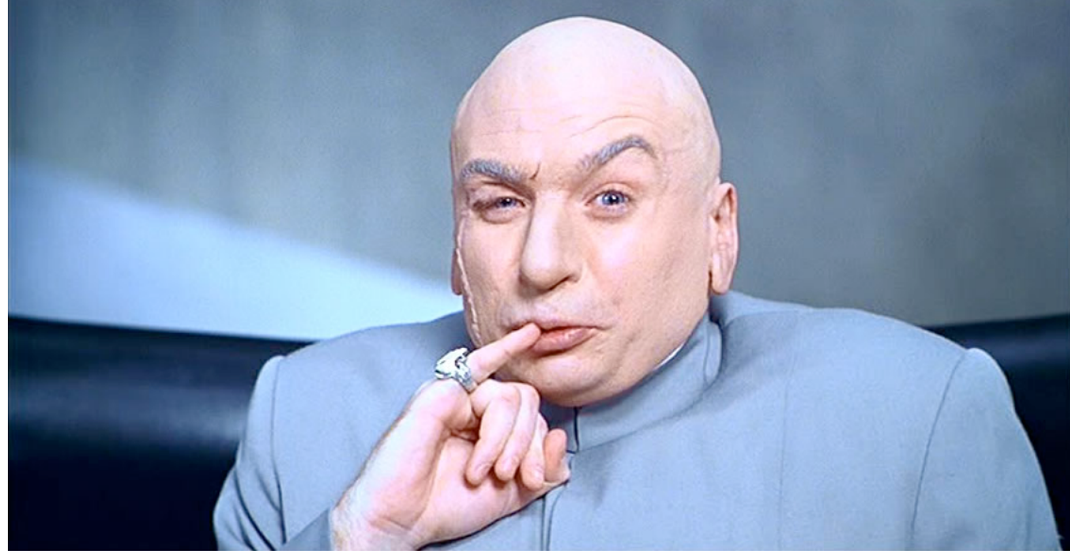
Ultrafaint dwarf satellite galaxies discovered by SDSS




L [L⊙]
10^3
10^4
10^5
10^6
10^7
10^8
10^9
Combined Correction
Fixed Coverage Correction
Uncorrected/Observed
Tollerud et al. (2008)
Correction: SDSS
less sensitive to fainter dwarfs
Correction: SDSS
didn't cover full sky
Ultrafaint
dwarfs
discovered
in SDSS
N(<M_V)
10^2
10^1
10^0
−2
−4
−6
−8
−10
−12
−14
−16
M_V

Feedback





Need non-linear mapping between properties of dark matter halos and observed, luminous galaxies

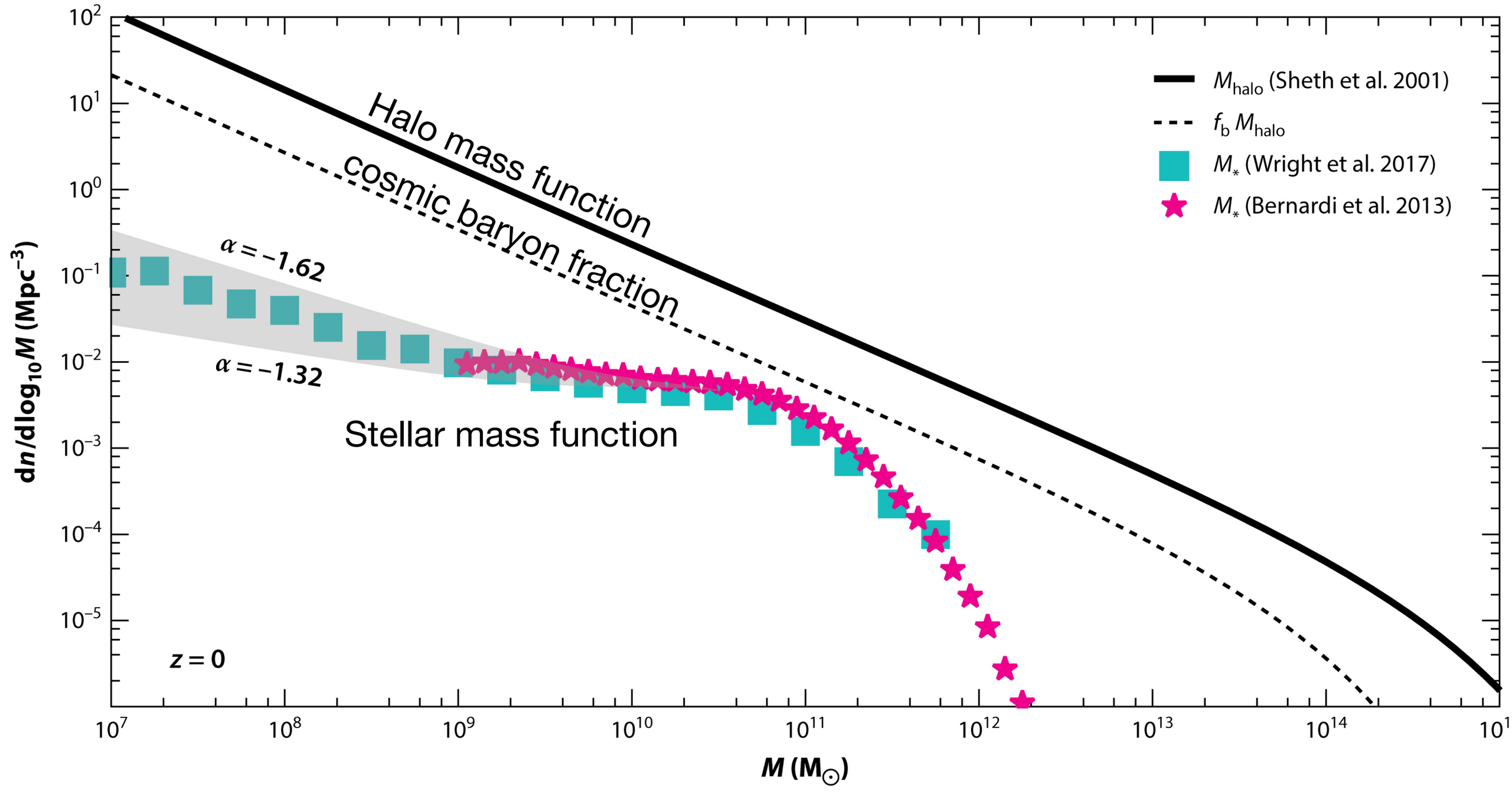
It does not work to make the obvious assumption

$$M_{tot} \propto L$$

One infers the presence of numerous dark sub-halos

Halo and stellar mass function

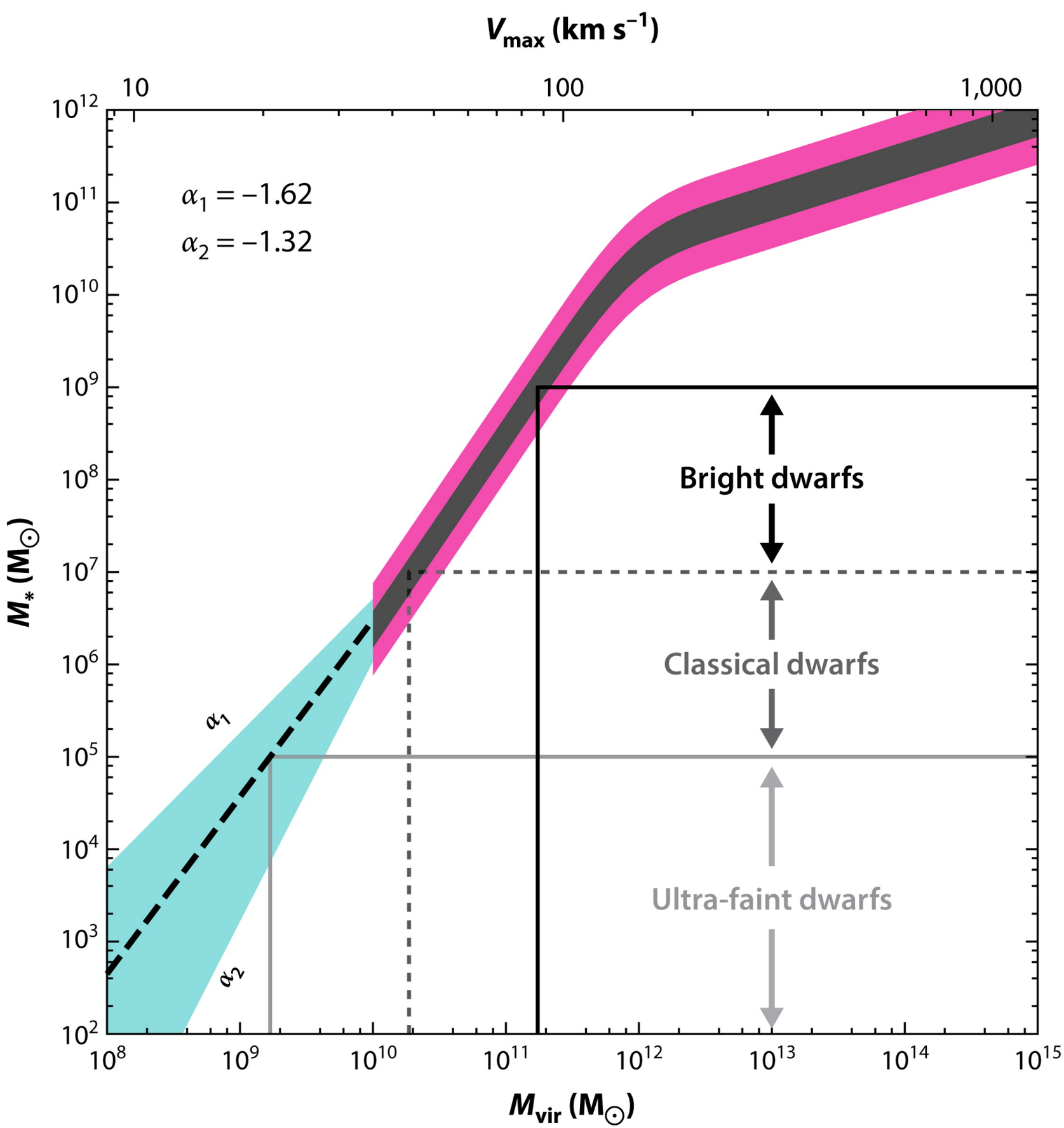
(Bullock & Boylan-Kolchin)



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

Abundance Matching

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



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

“Moster relation”

Moster et al (2013)

From
“abundance matching”

Match the number density of simulated dark matter halos to that observed for galaxies as a fcn of mass

Note that a large range in stellar mass gets wedged into a narrow range in halo mass.