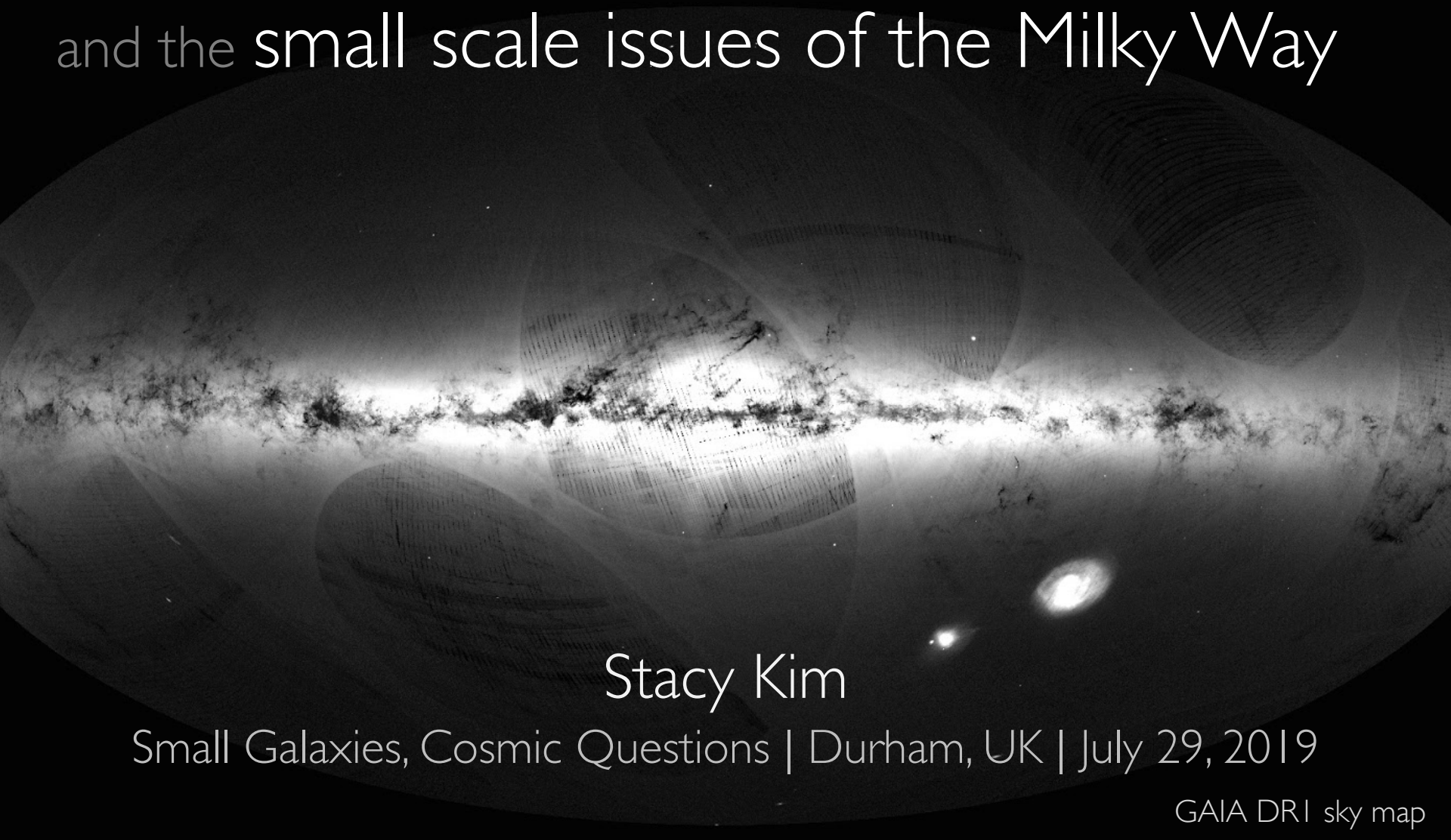
completeness corrections

and the small scale issues of the Milky Way



Stacy Kim

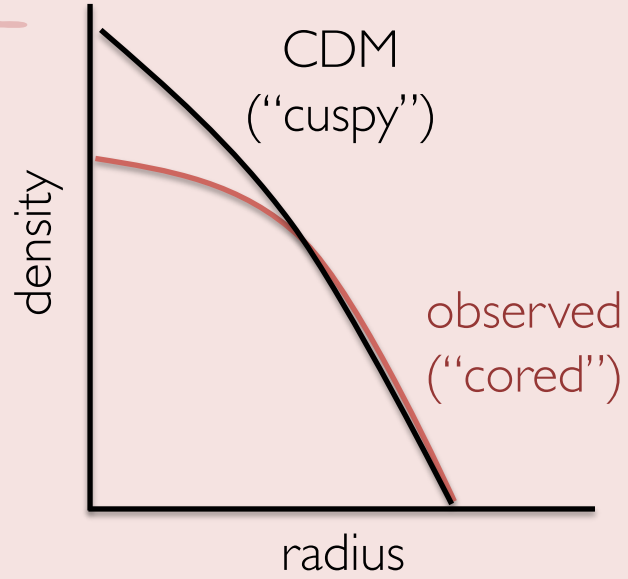
Small Galaxies, Cosmic Questions | Durham, UK | July 29, 2019

GAIA DR1 sky map

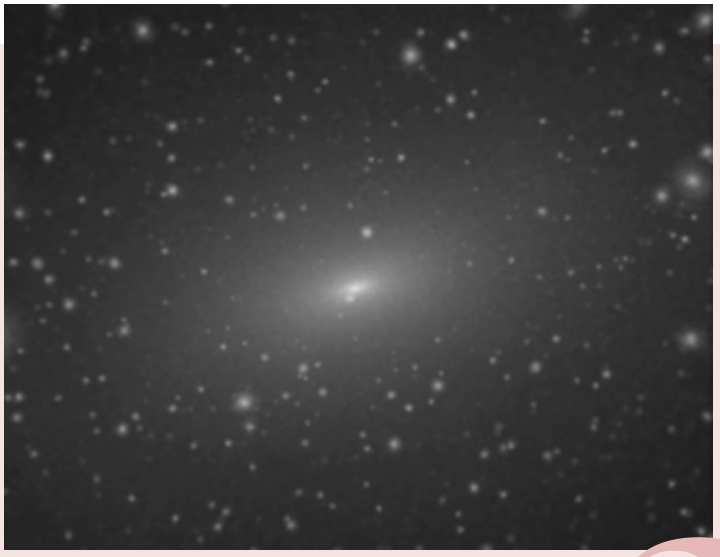
Two fundamental predictions of CDM

1

DM halos are cuspy in their centers, i.e. $\rho \propto r^{-1}$



cusp-core problem

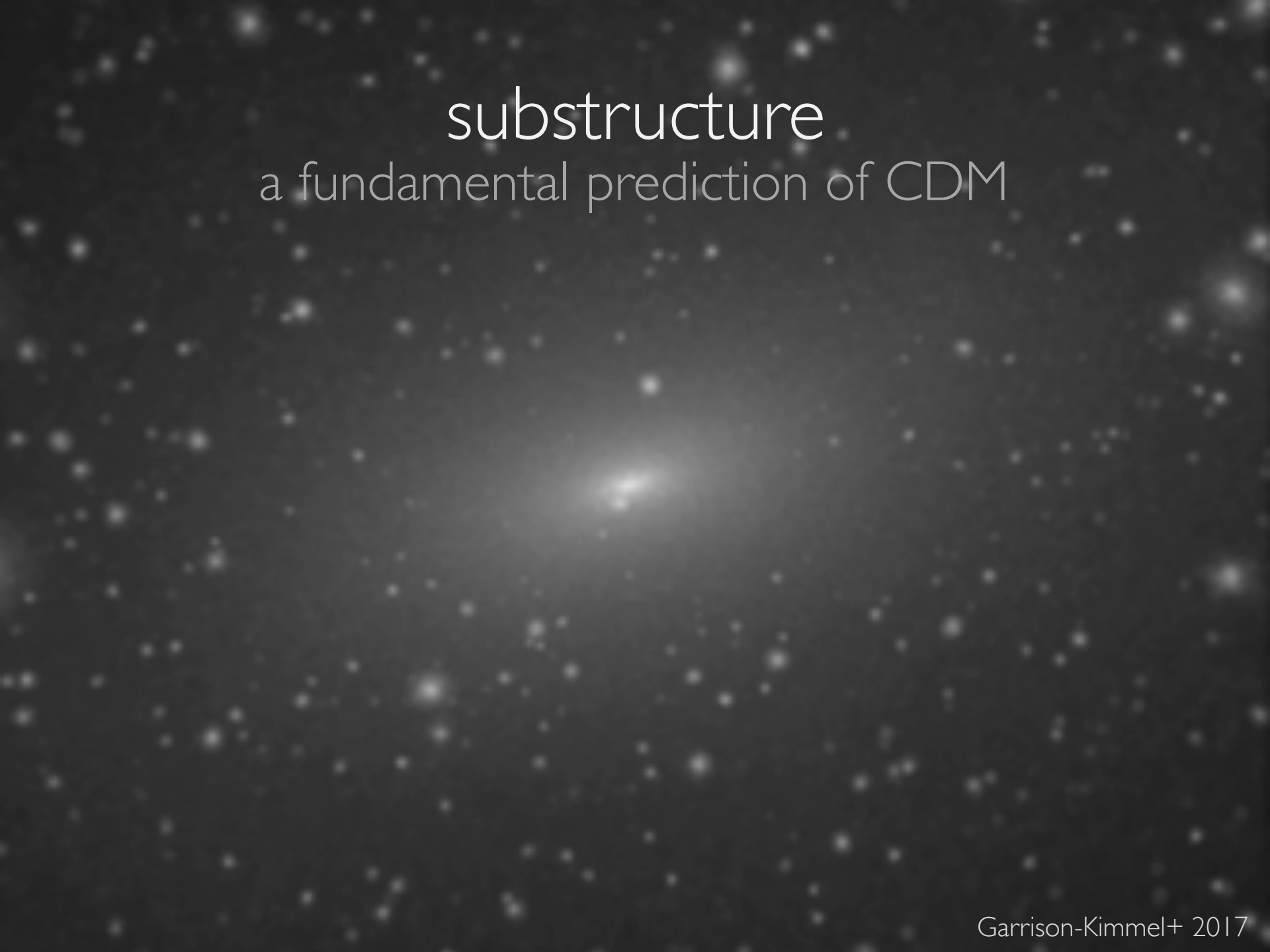


2

Nearly scale-free hierarchy of DM halos

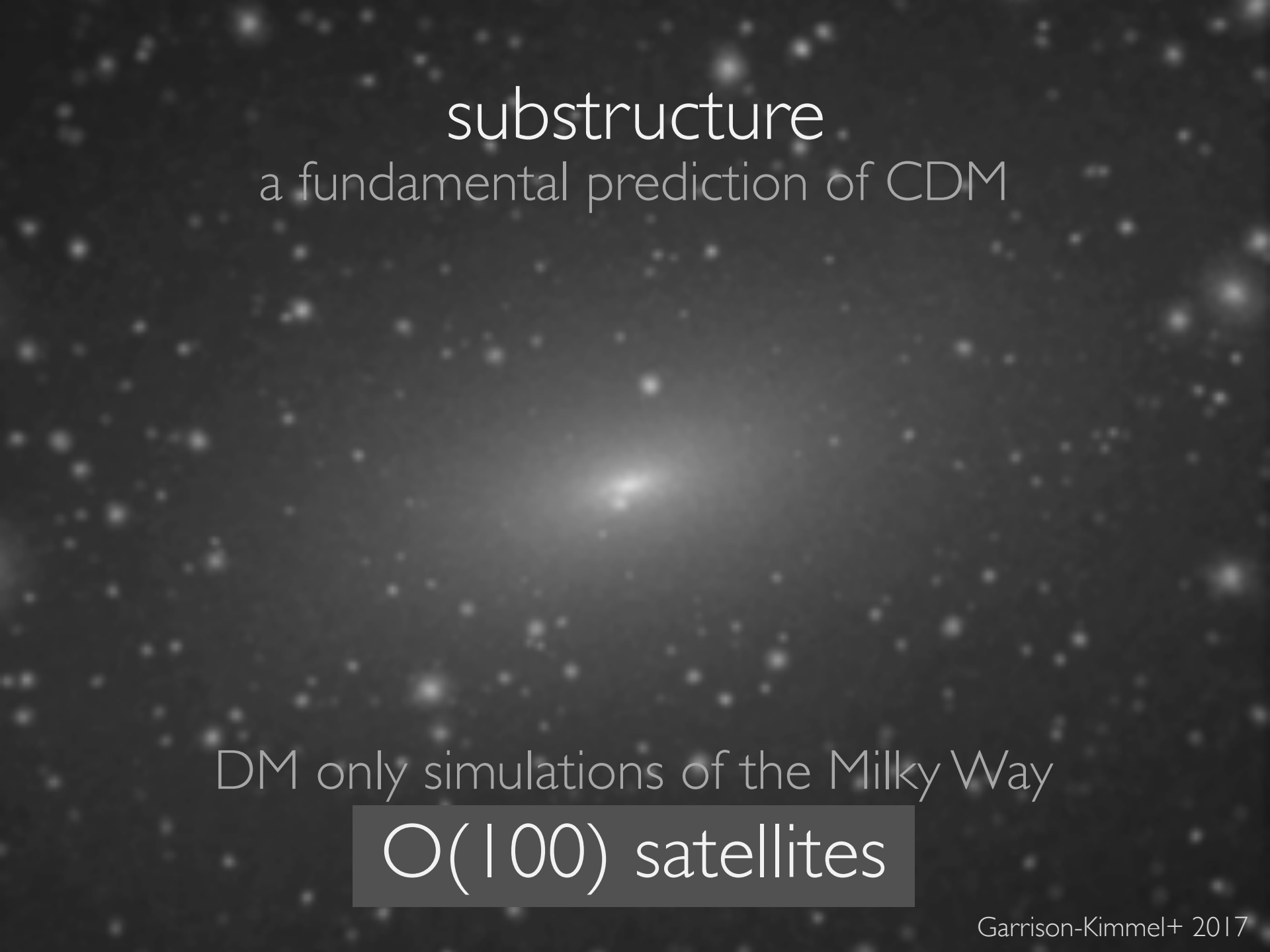
to Earth-mass scales!

missing satellites problem


substructure
a fundamental prediction of CDM
Garrison-Kimmel+ 2017

substructure

a fundamental prediction of CDM

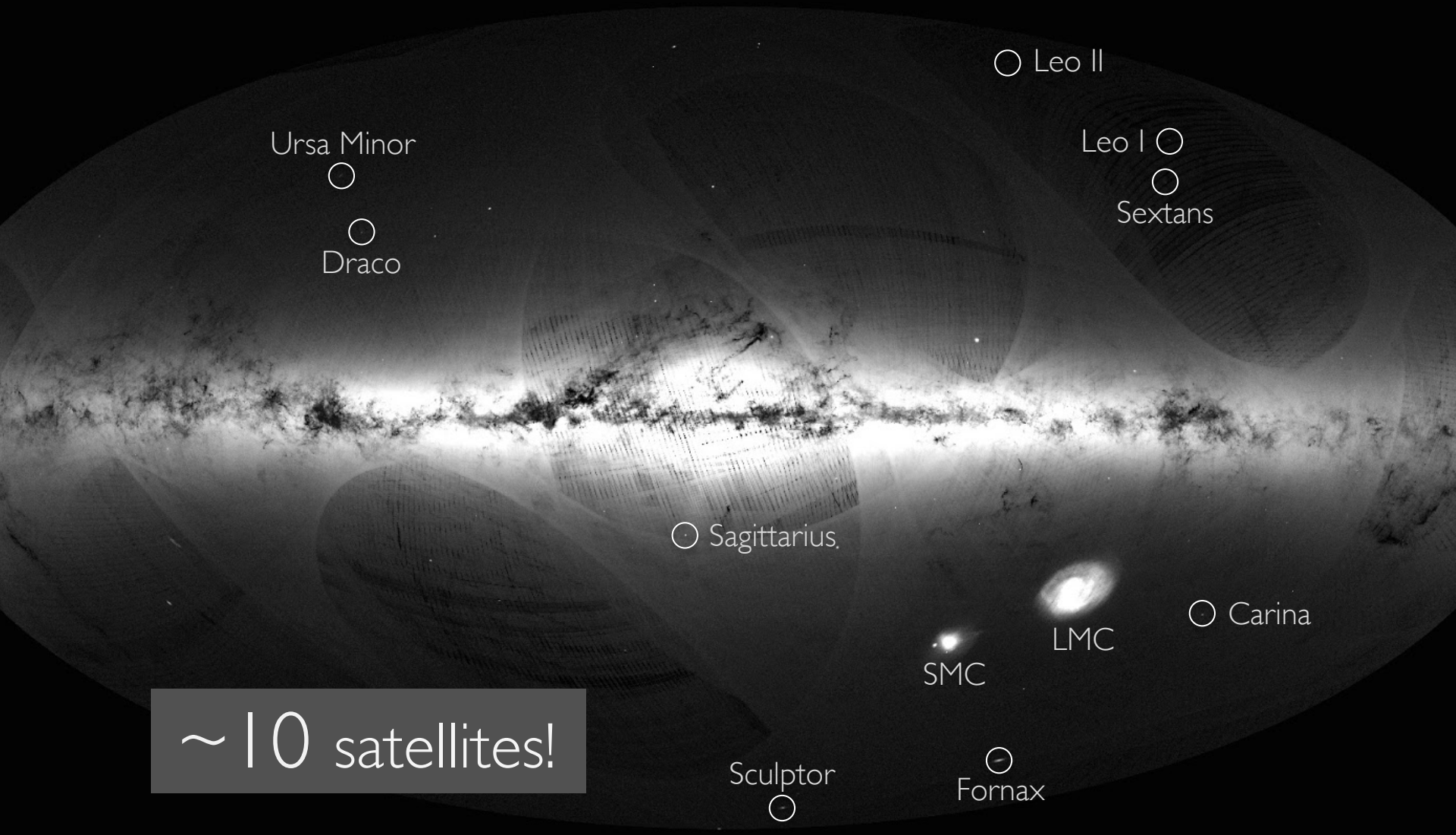


DM only simulations of the Milky Way

O(100) satellites

Garrison-Kimmel+ 2017

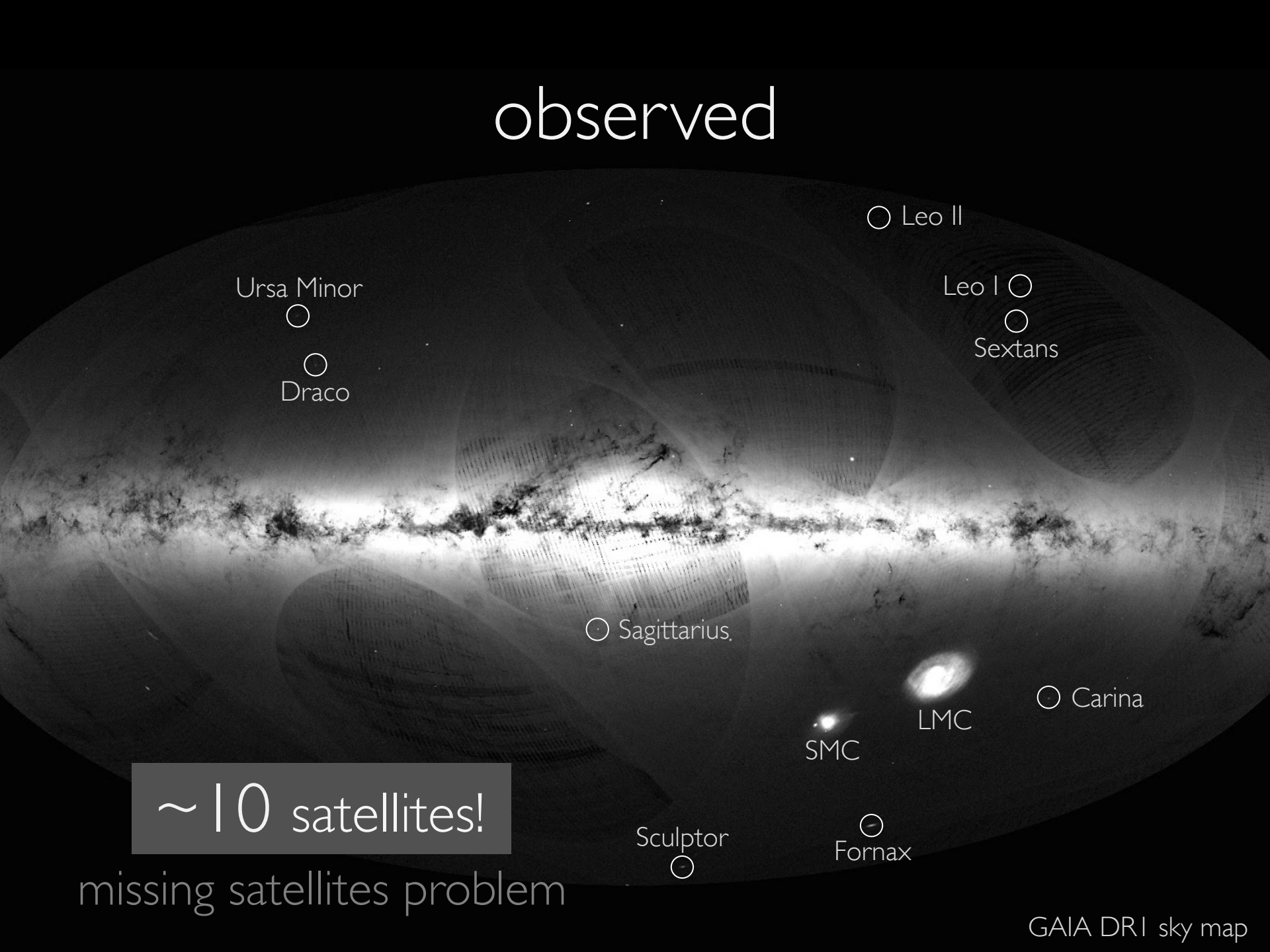
observed



~10 satellites!

GAIA DR1 sky map

observed

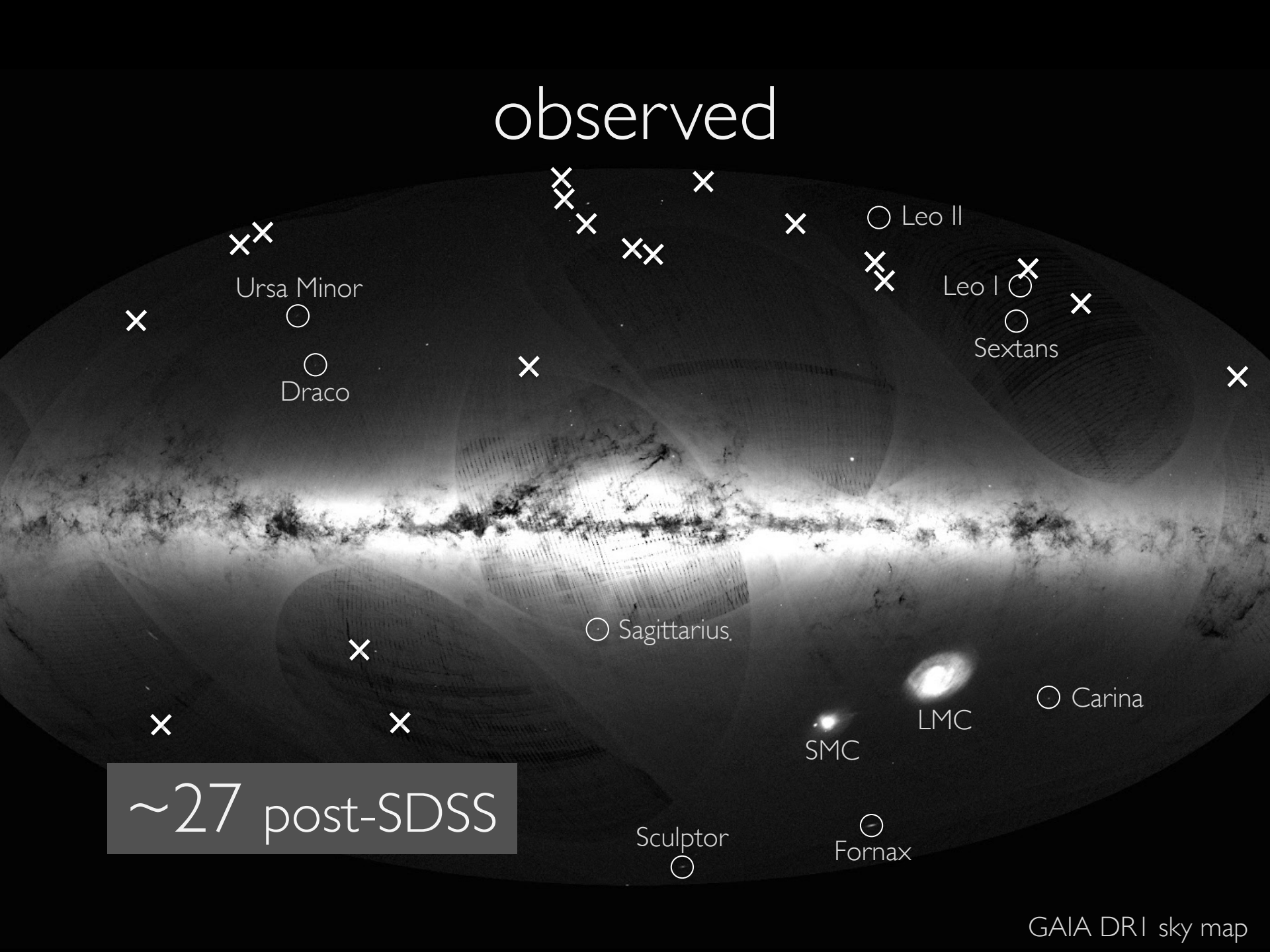


~10 satellites!

missing satellites problem

GAIA DR1 sky map

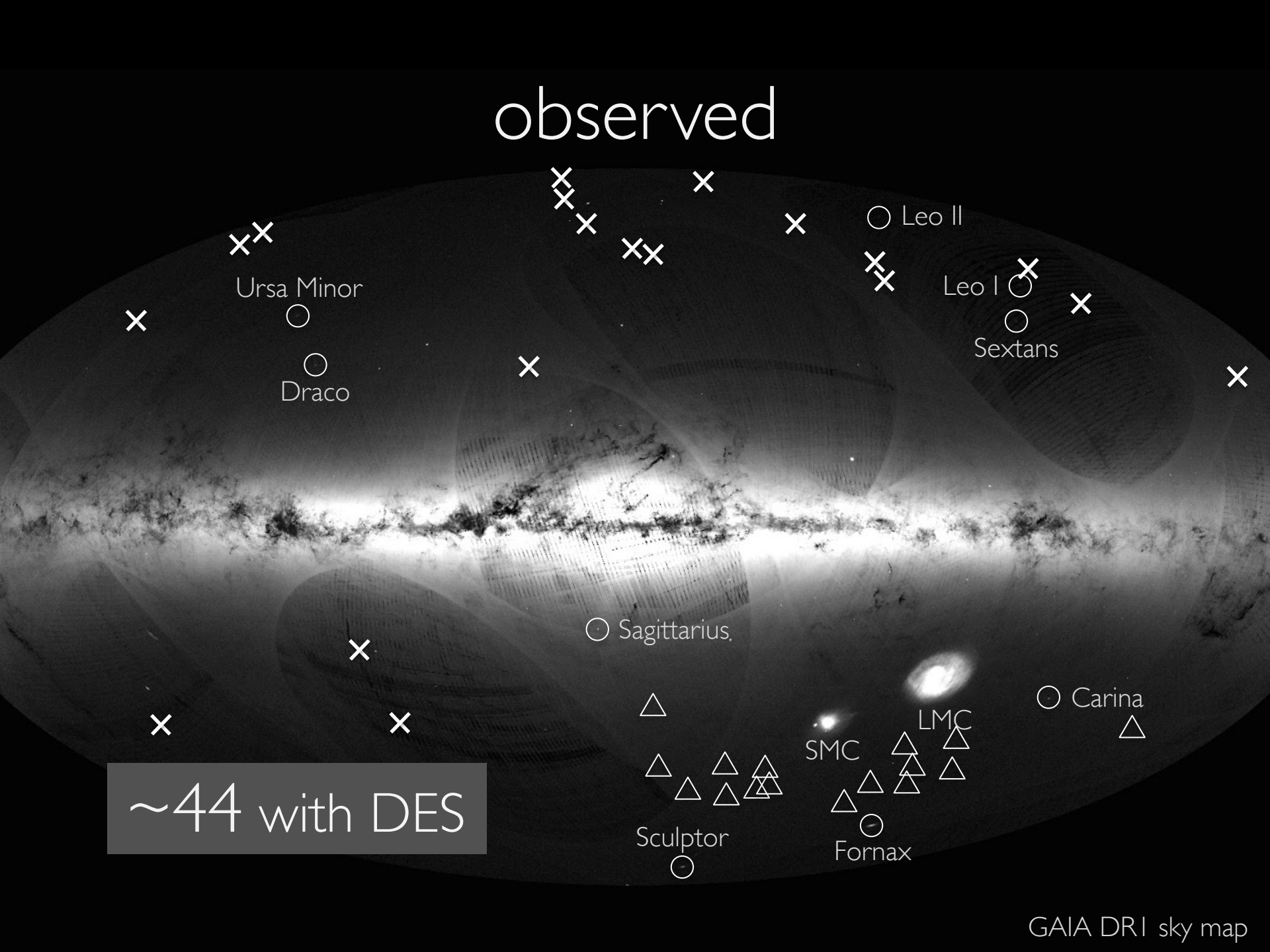
observed



~27 post-SDSS

GAIA DR1 sky map

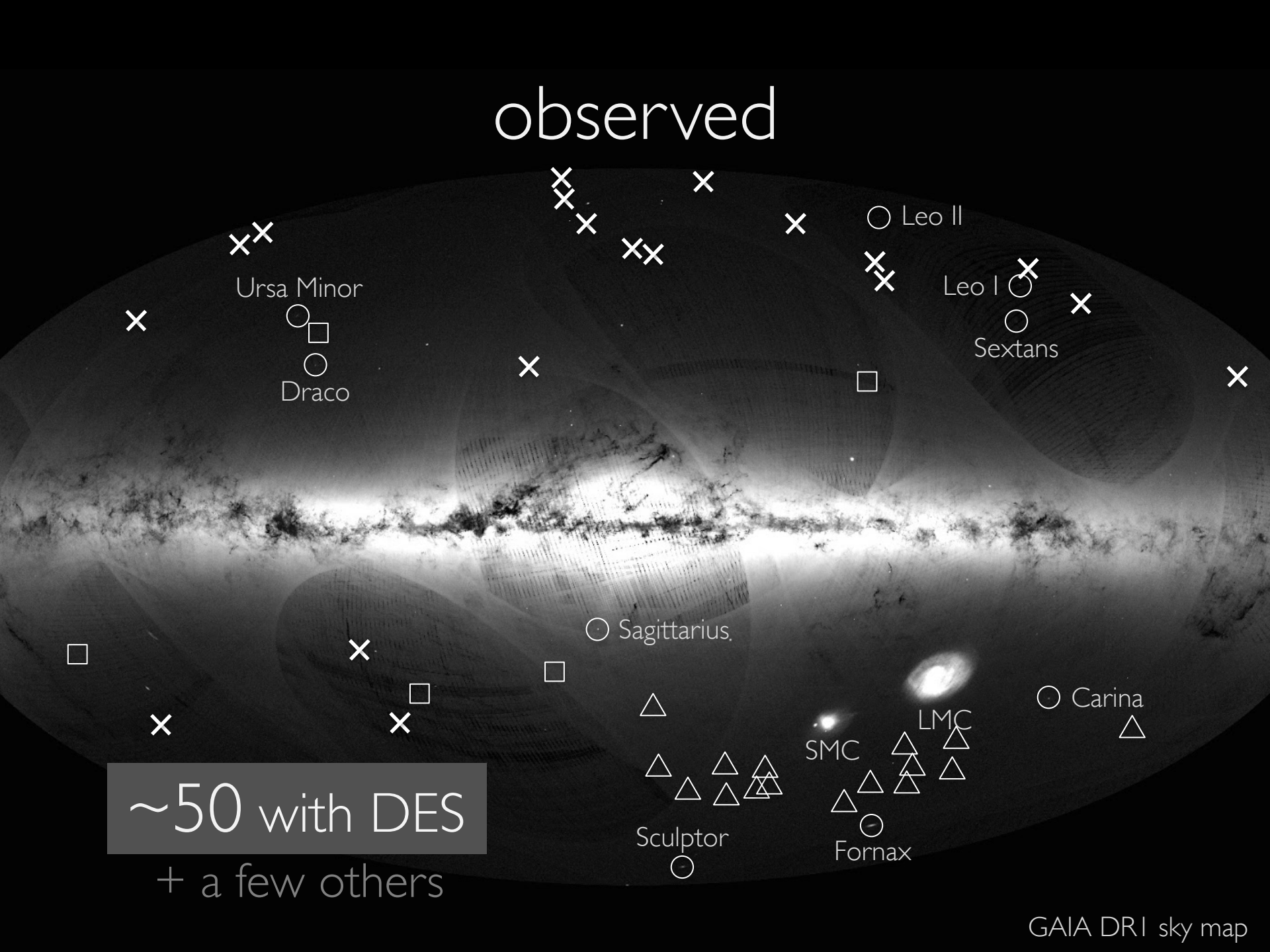
observed



~44 with DES

GAIA DR1 sky map

observed

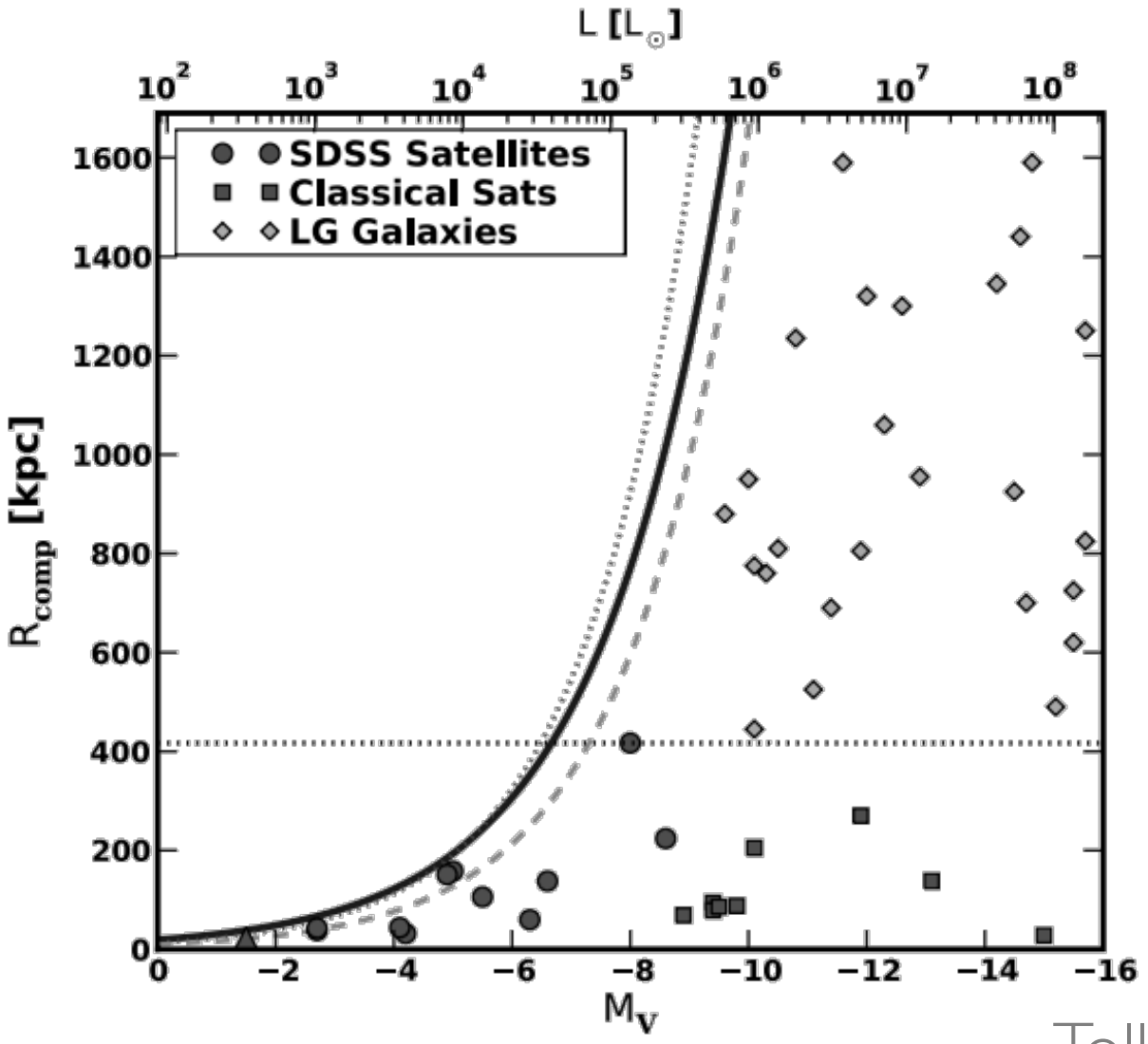


~50 with DES

+ a few others

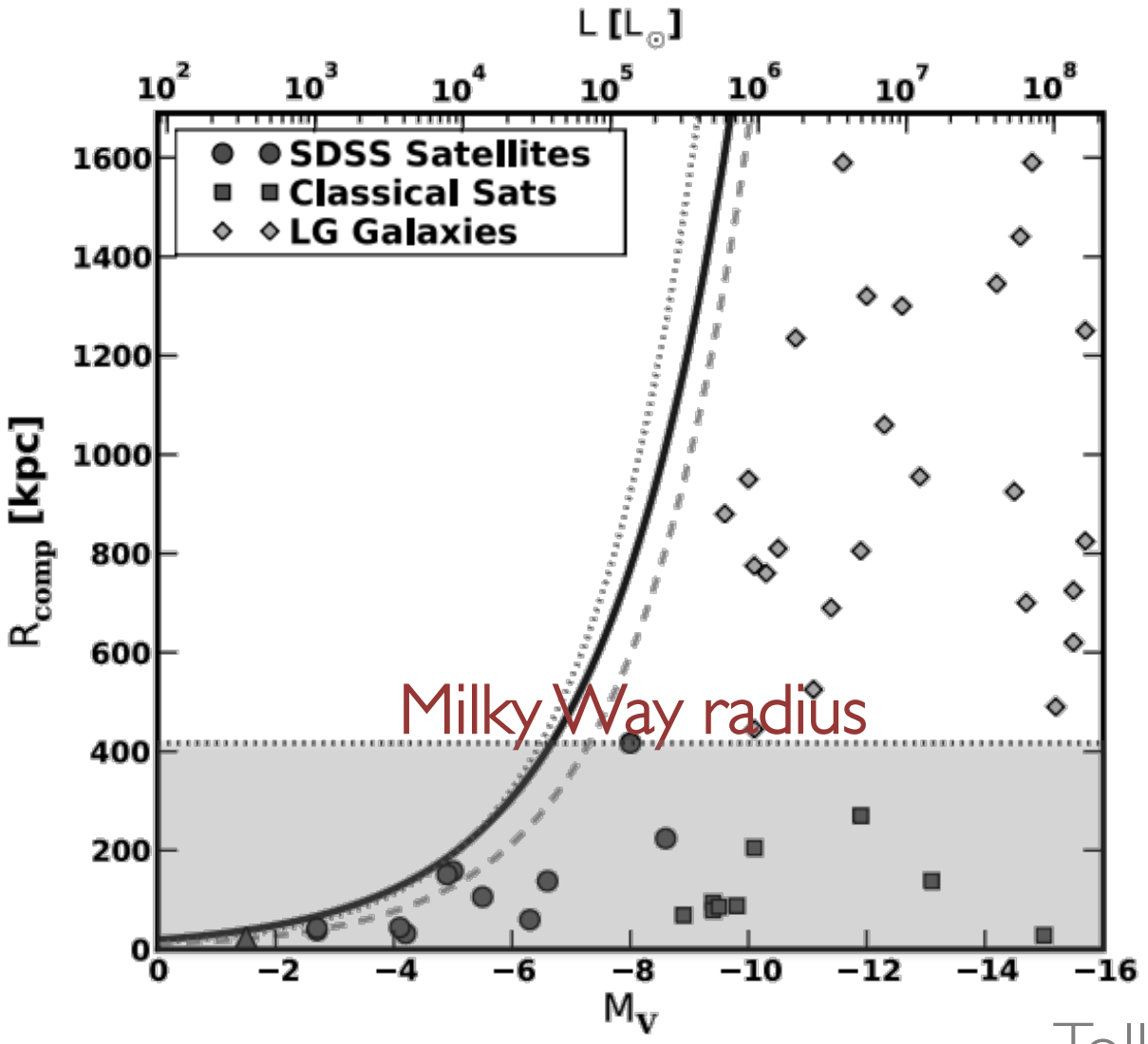
GAIA DR1 sky map

where's the rest?



Tollerud+ 2008

where's the rest?



Tollerud+ 2008

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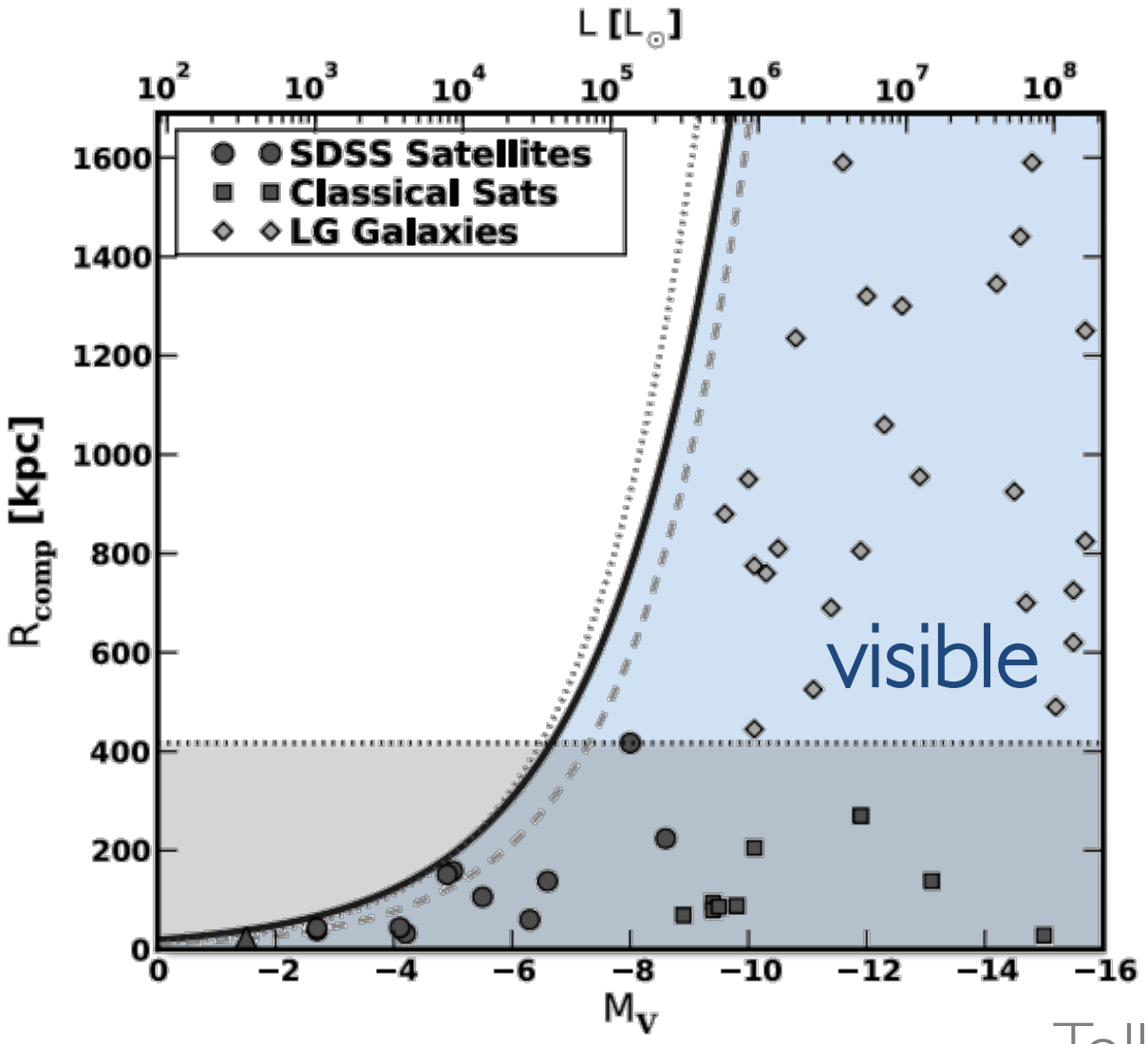
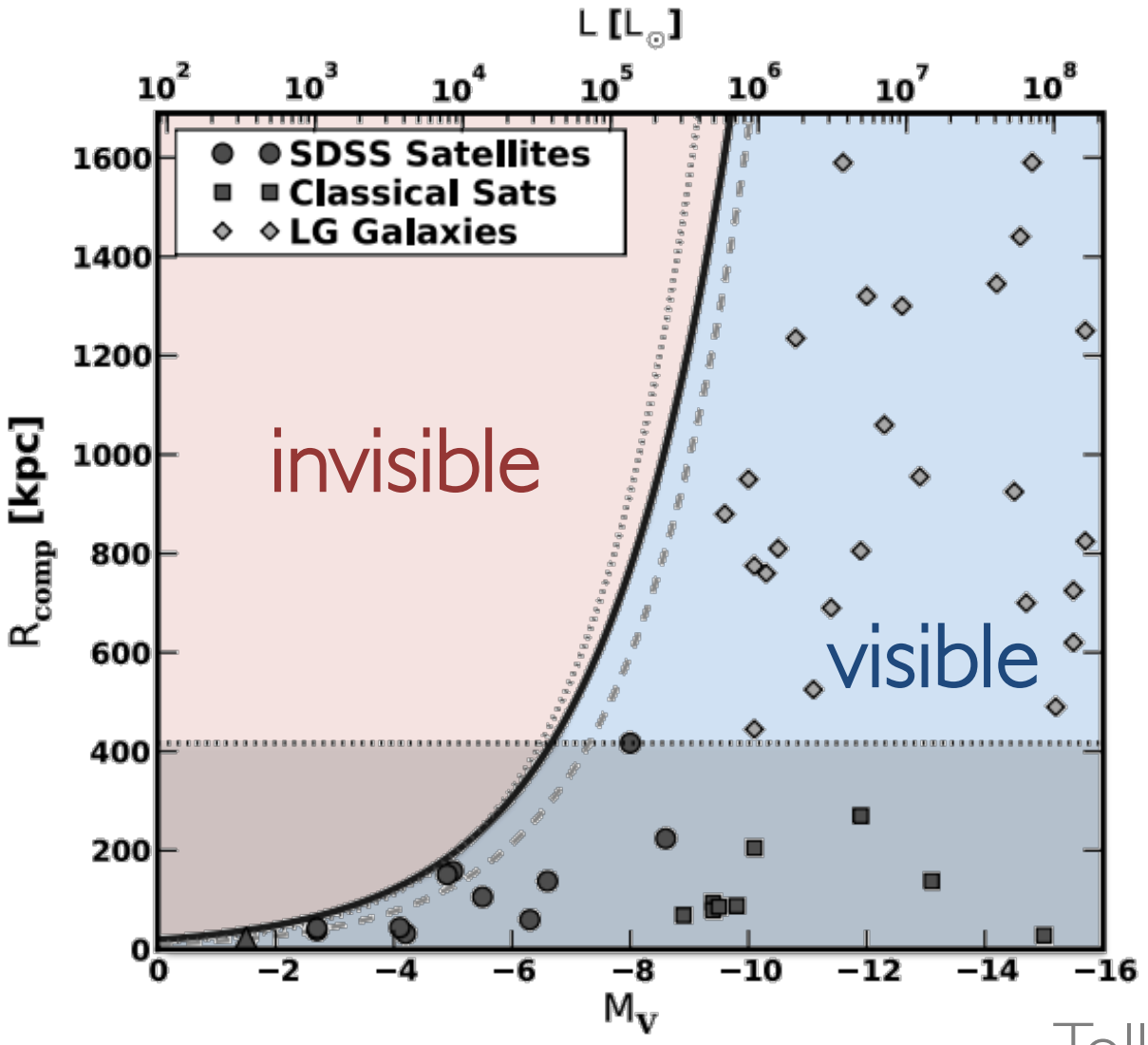


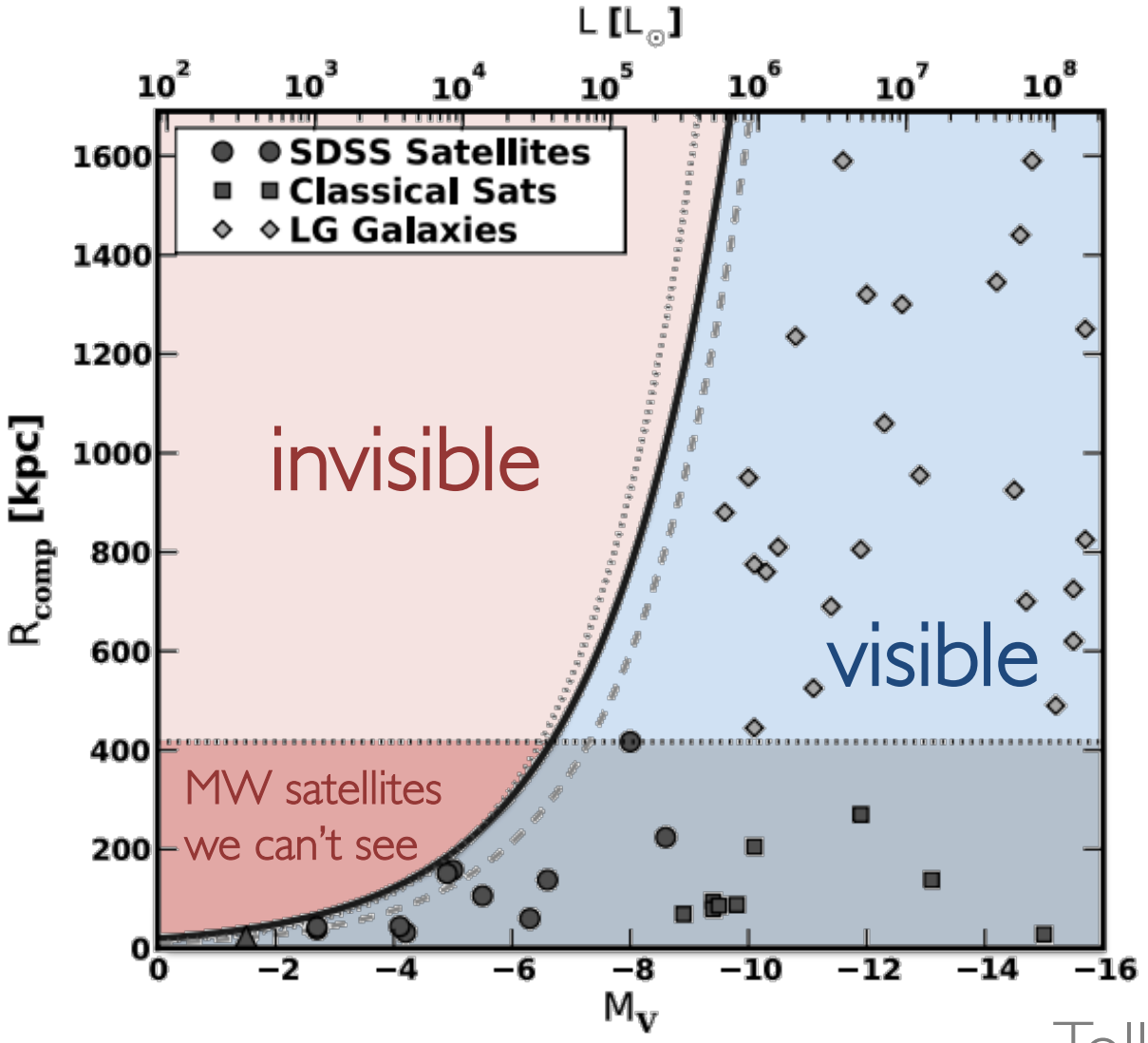
Tollerud+ 2008

where's the rest?



Tollerud+ 2008

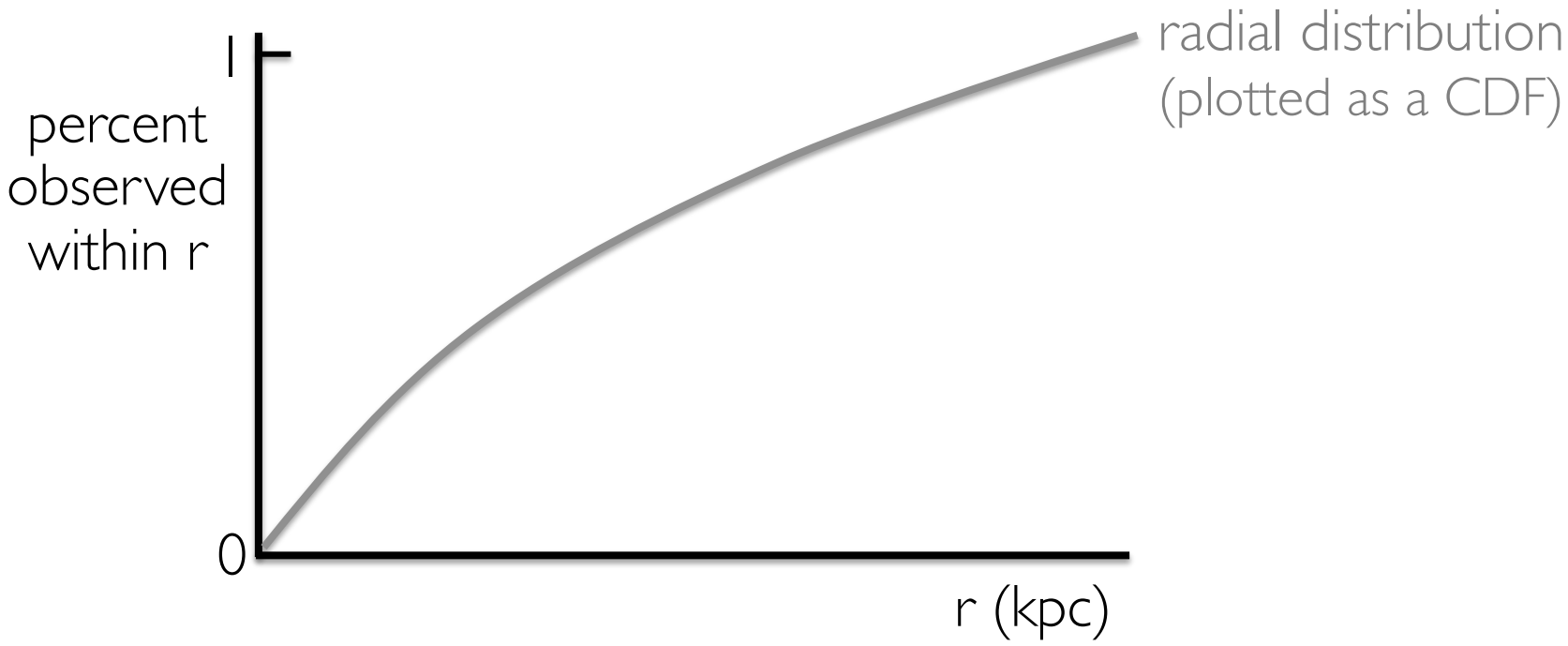
where's the rest?



Tollerud+ 2008

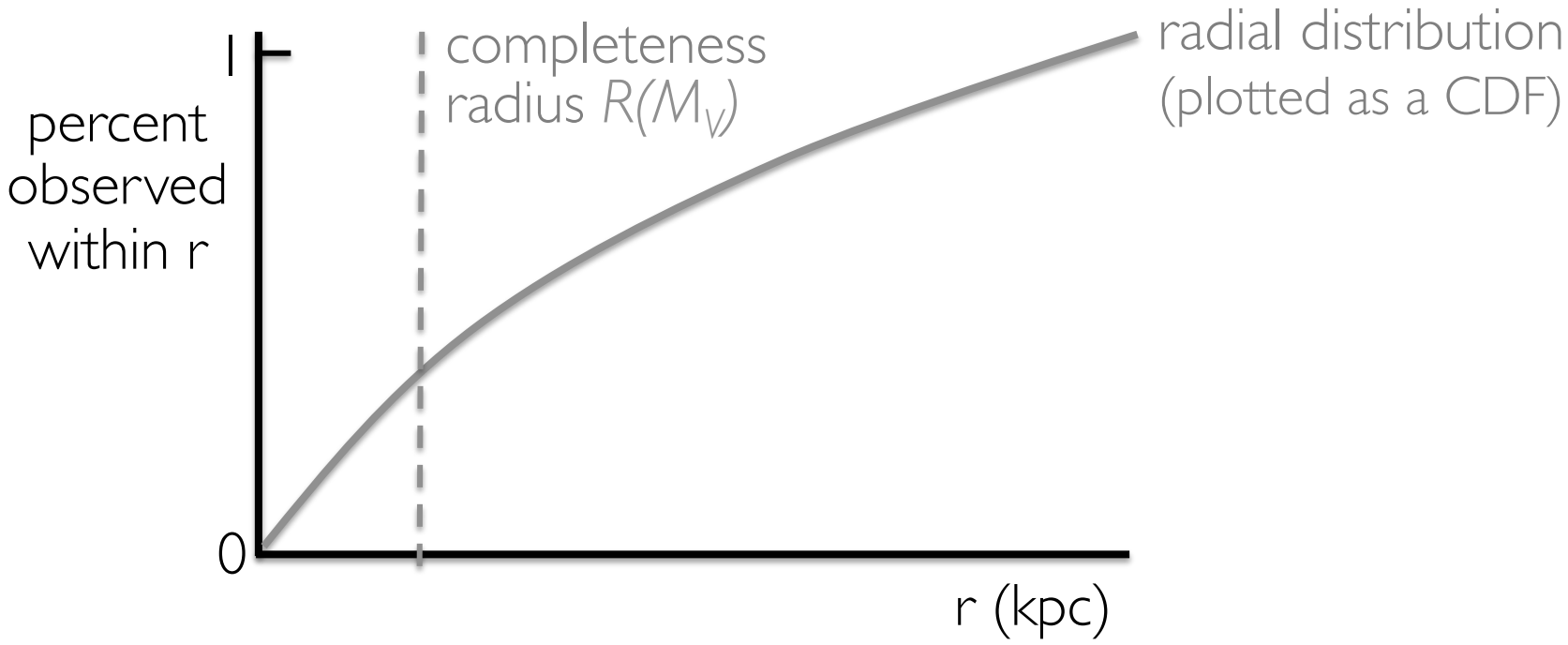
completeness corrections

completeness corrections



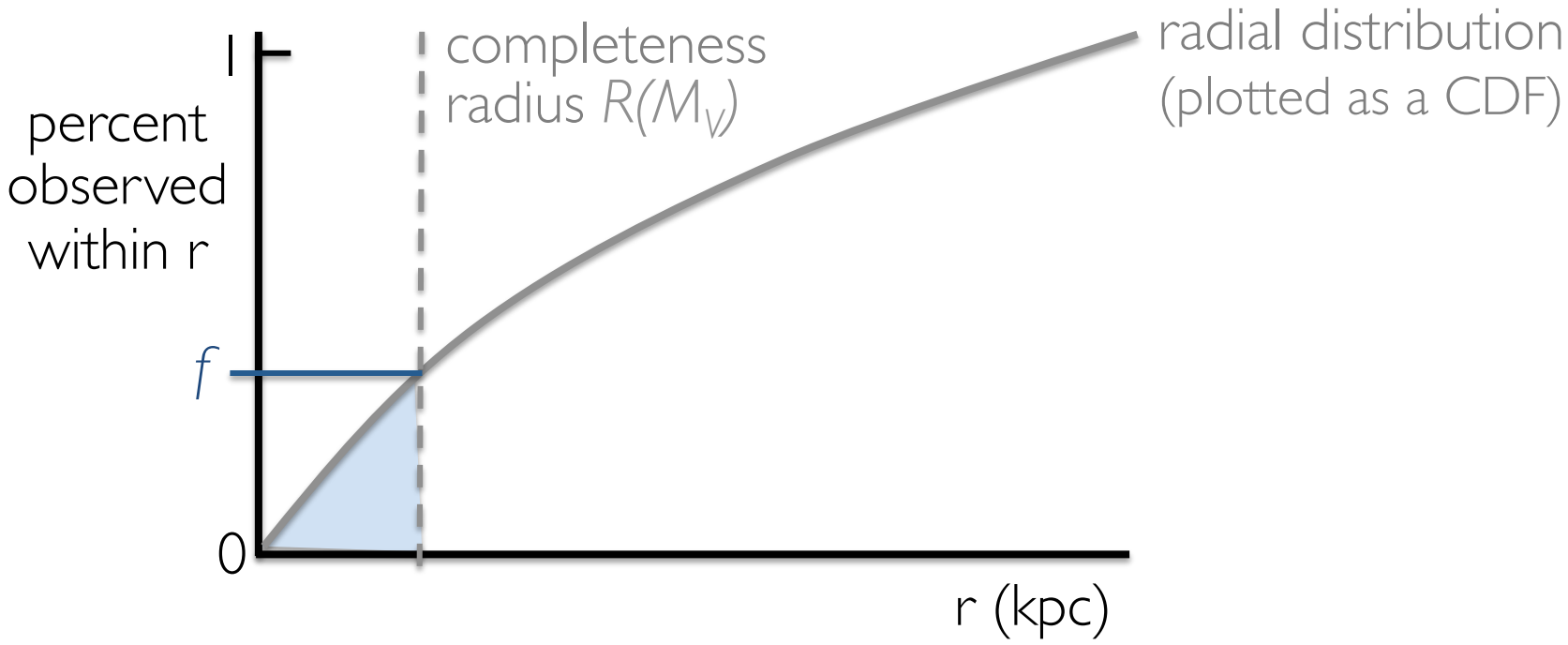
completeness corrections

for each dwarf observed, with brightness M_V,



completeness corrections

for each dwarf observed, with brightness M_V,



completeness corrections

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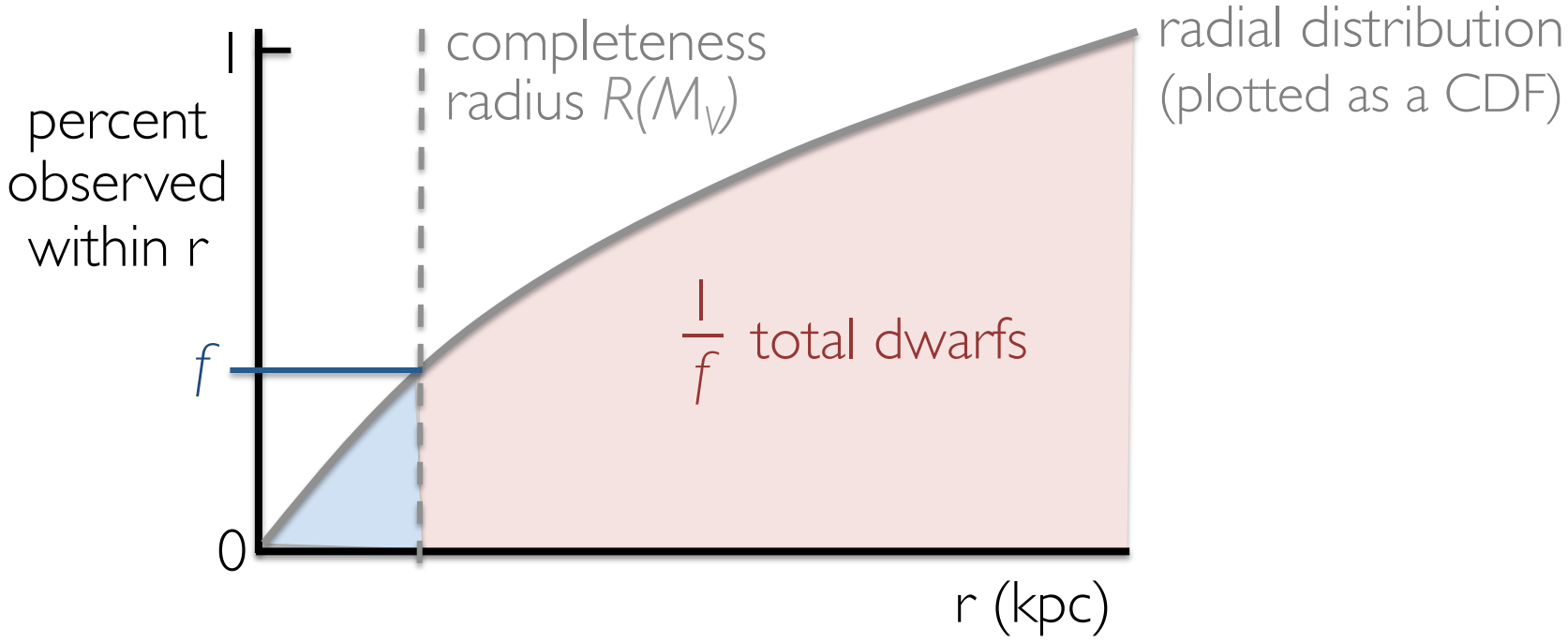
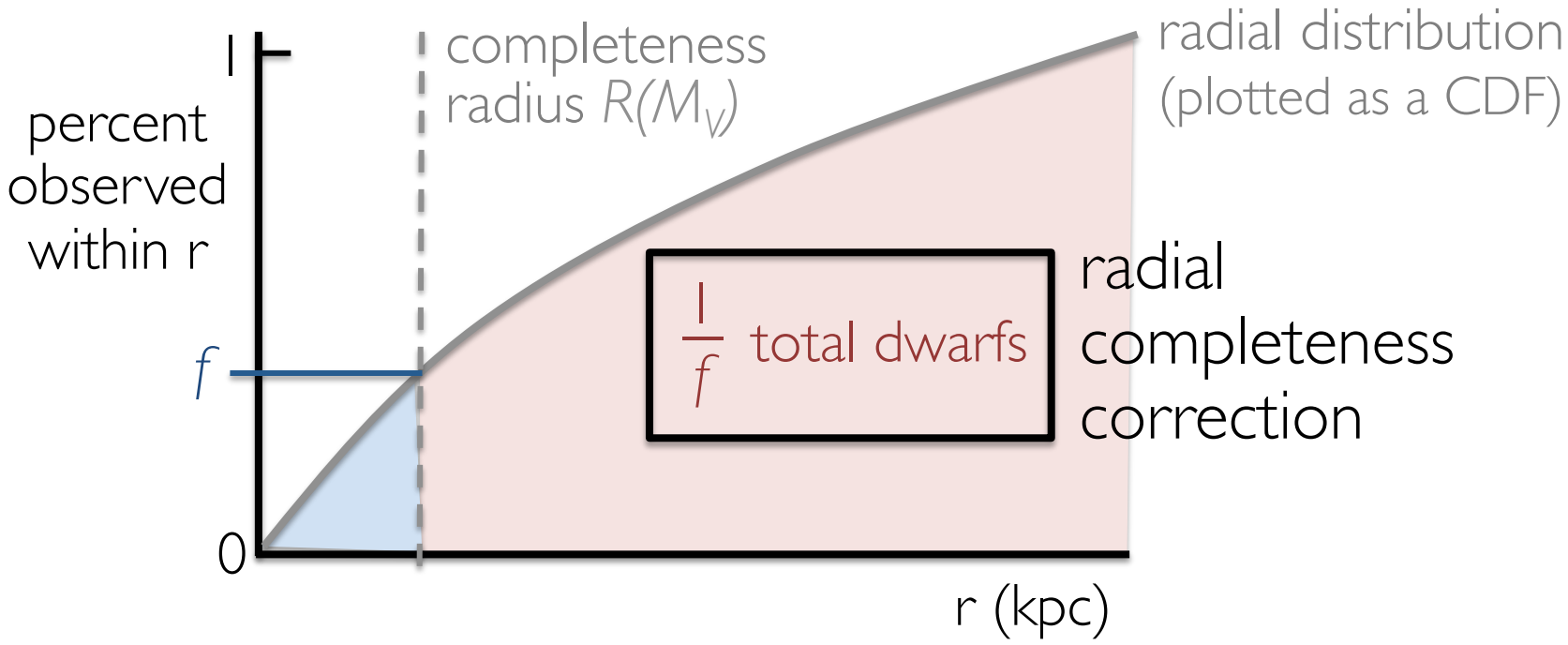


completeness corrections

for each dwarf observed, with brightness M_V,



completeness corrections

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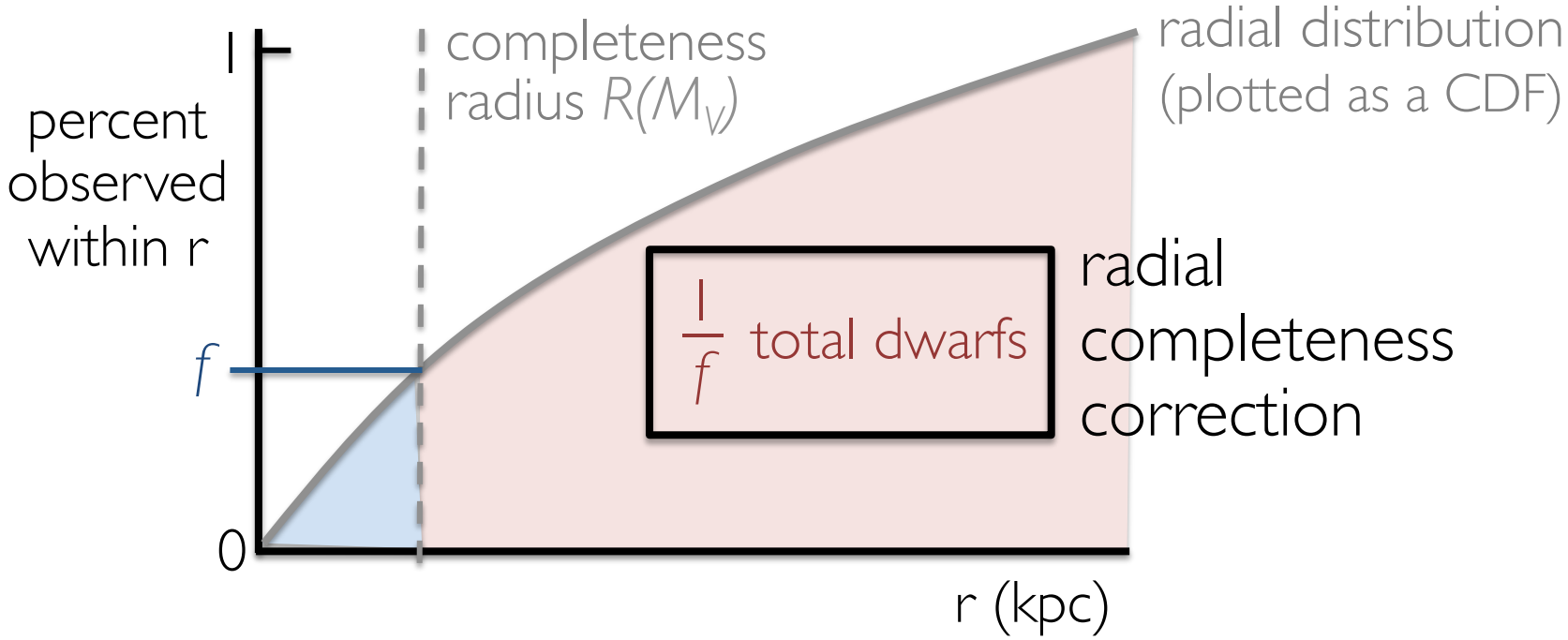
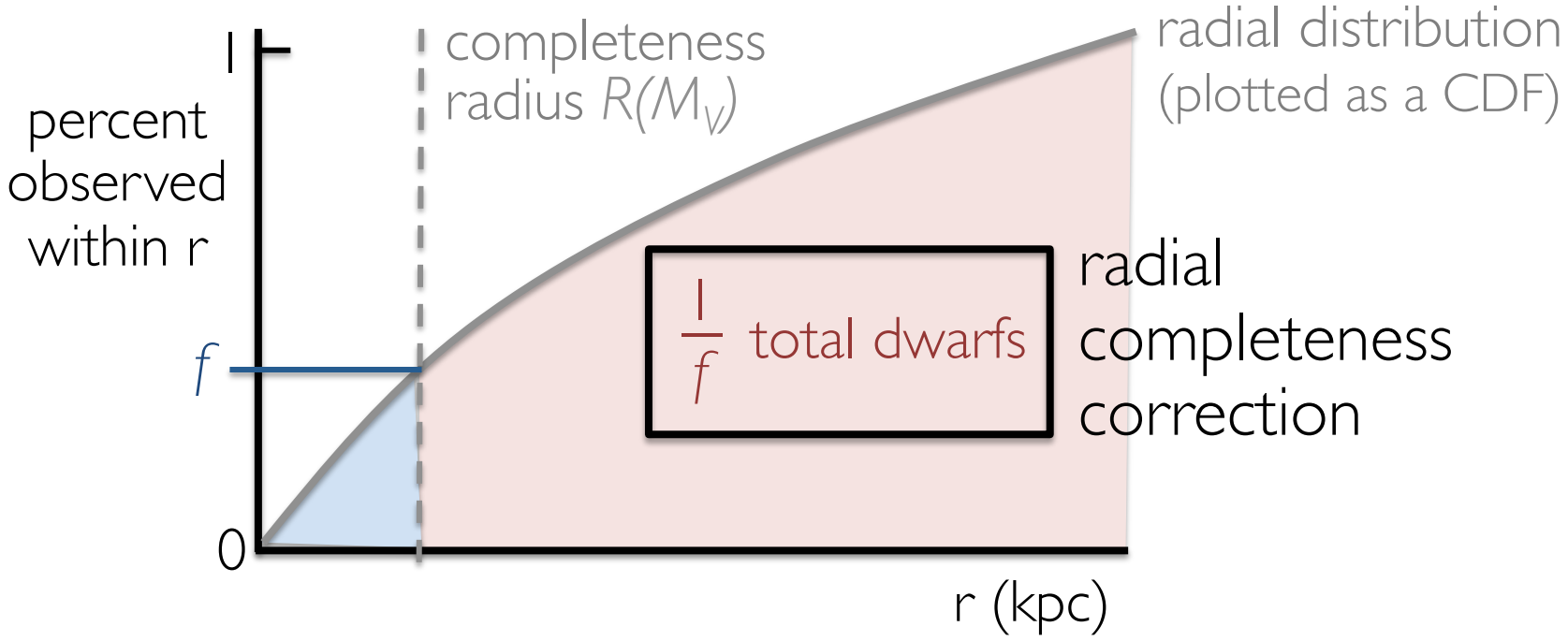


$\frac{A_{sky}}{A}$ area completeness correction

survey area

completeness corrections

for each dwarf observed, with brightness M_V,



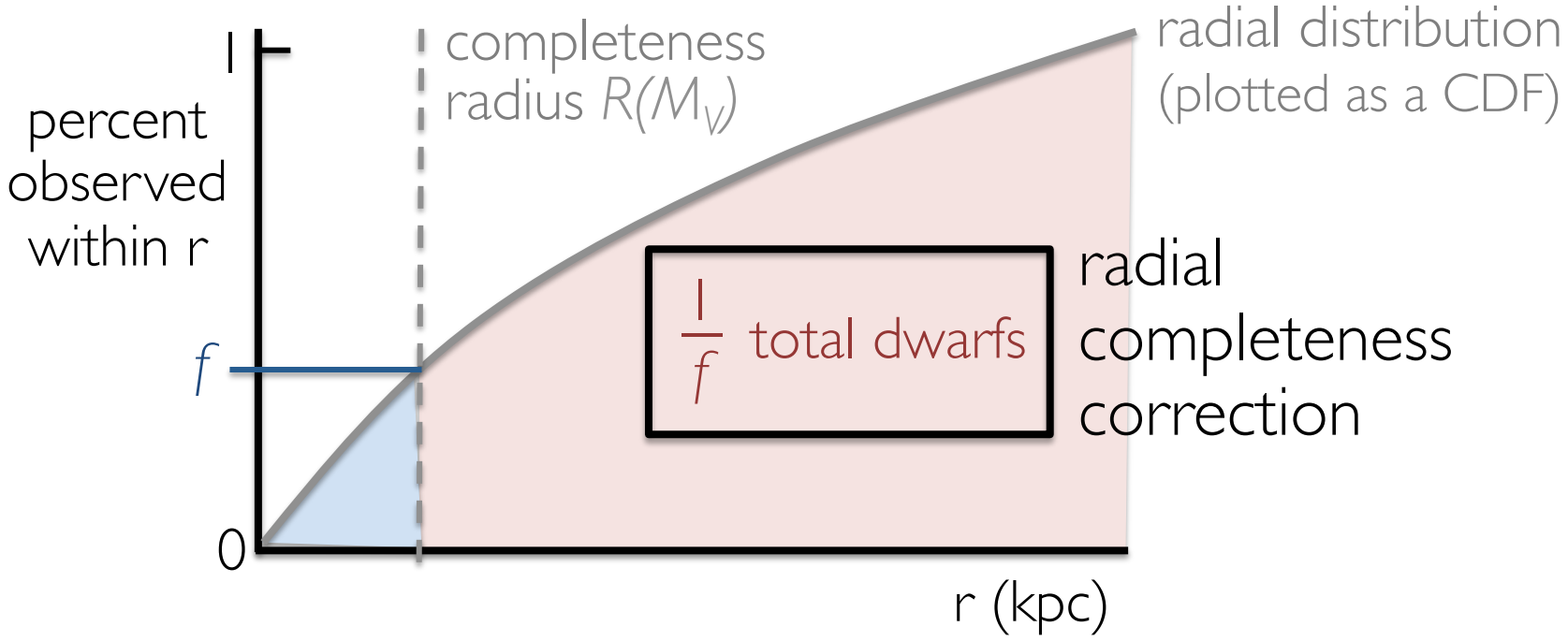
$\frac{A_{sky}}{A}$ area completeness correction

survey area

$$\text{total dwarfs with } M_V = \frac{1}{f}\frac{A_{sky}}{A}$$

completeness corrections

for each dwarf observed, with brightness M_V,



$\frac{A_{sky}}{A}$ area completeness correction

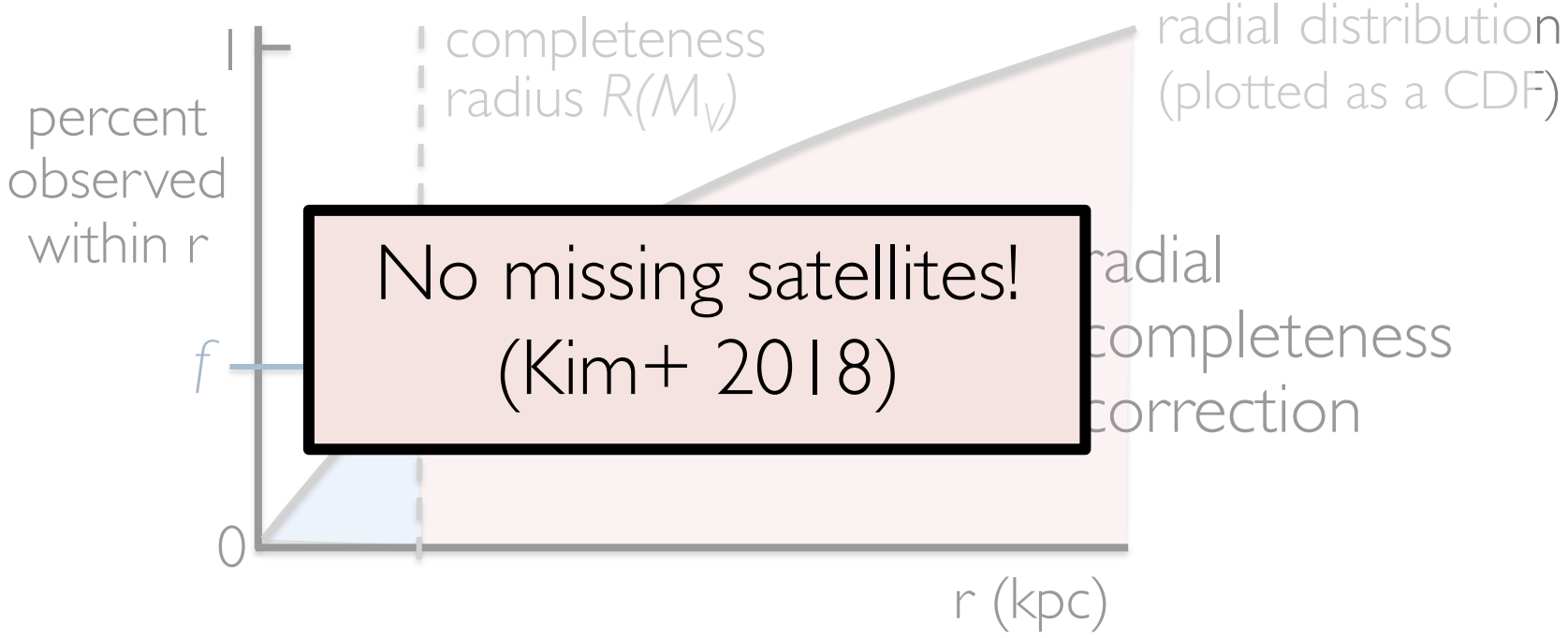
survey area

$$\text{total dwarfs with } M_V = \frac{1}{f}\frac{A_{sky}}{A}$$

sum for each dwarf, MW total

completeness corrections

for each dwarf observed, with brightness M_V,



No missing satellites!
(Kim+ 2018)

$\frac{A_{sky}}{A}$ area completeness correction

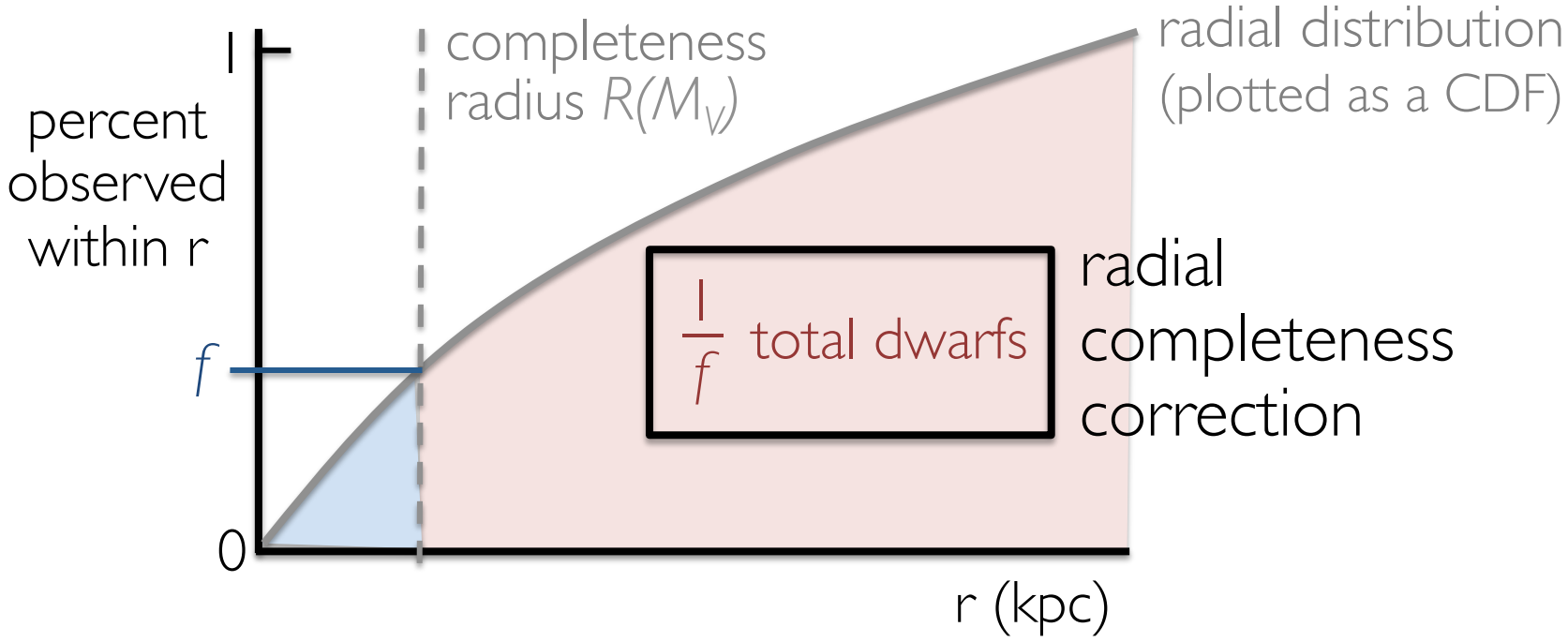
survey area

total dwarfs with M_V $= \frac{1}{f} \frac{A_{sky}}{A}$

sum for each dwarf, MW total

completeness corrections

for each dwarf observed, with brightness M_V, dispersion σ_*,



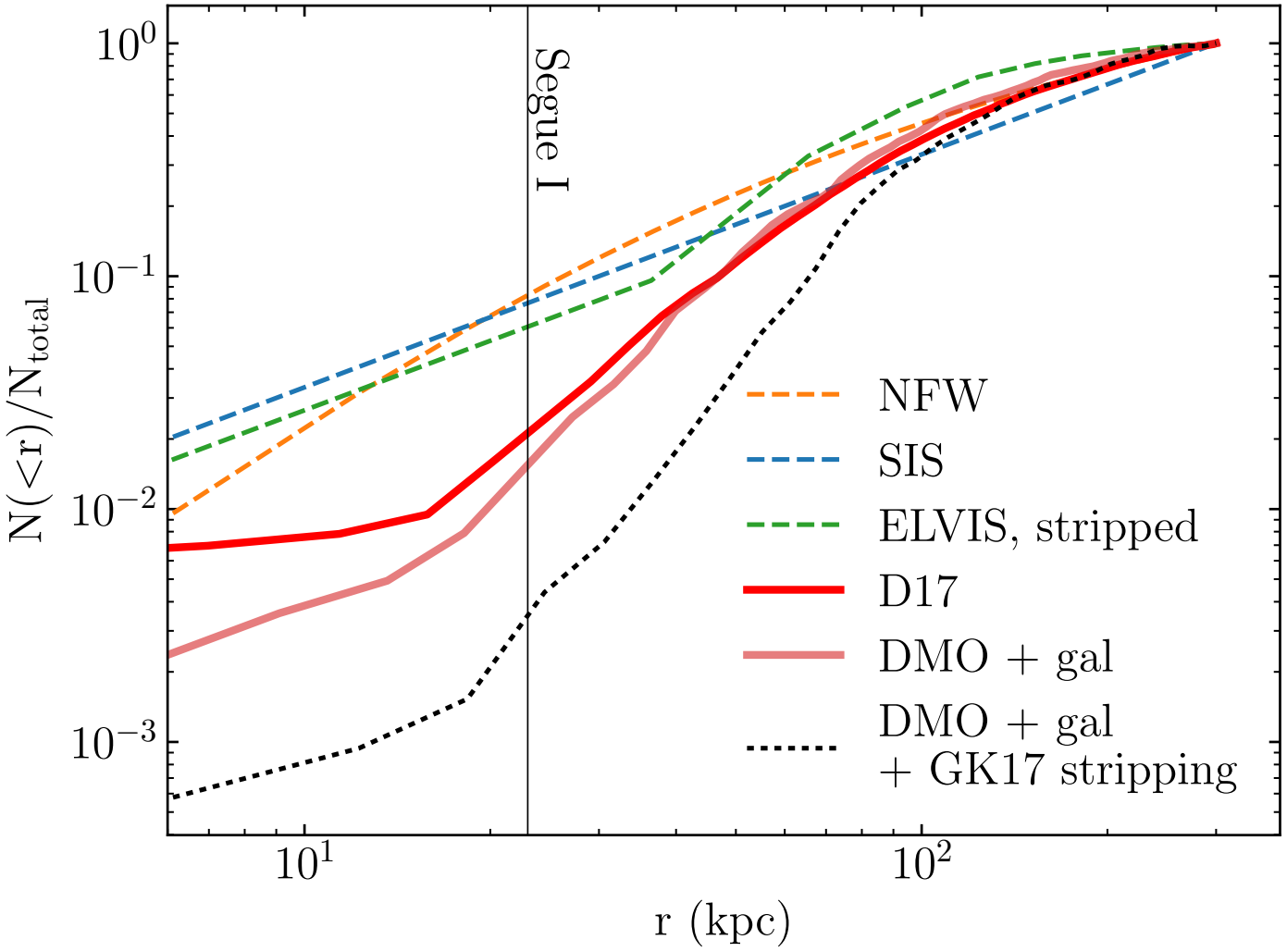
$\frac{A_{sky}}{A}$ area completeness correction

survey area

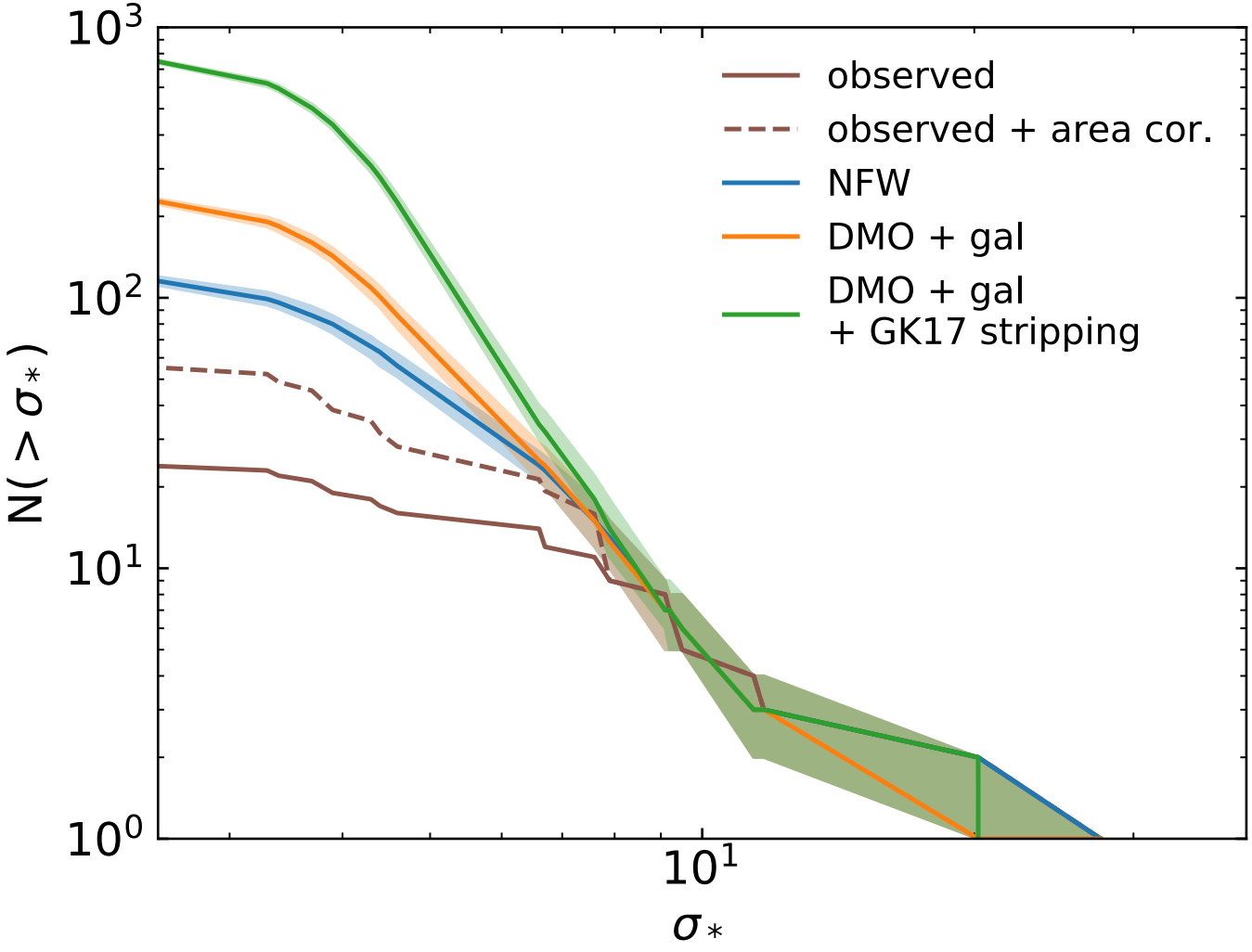
$$\text{total dwarfs with } \sigma_* = \frac{1}{f}\frac{A_{sky}}{A}$$

sum for each dwarf, MW total

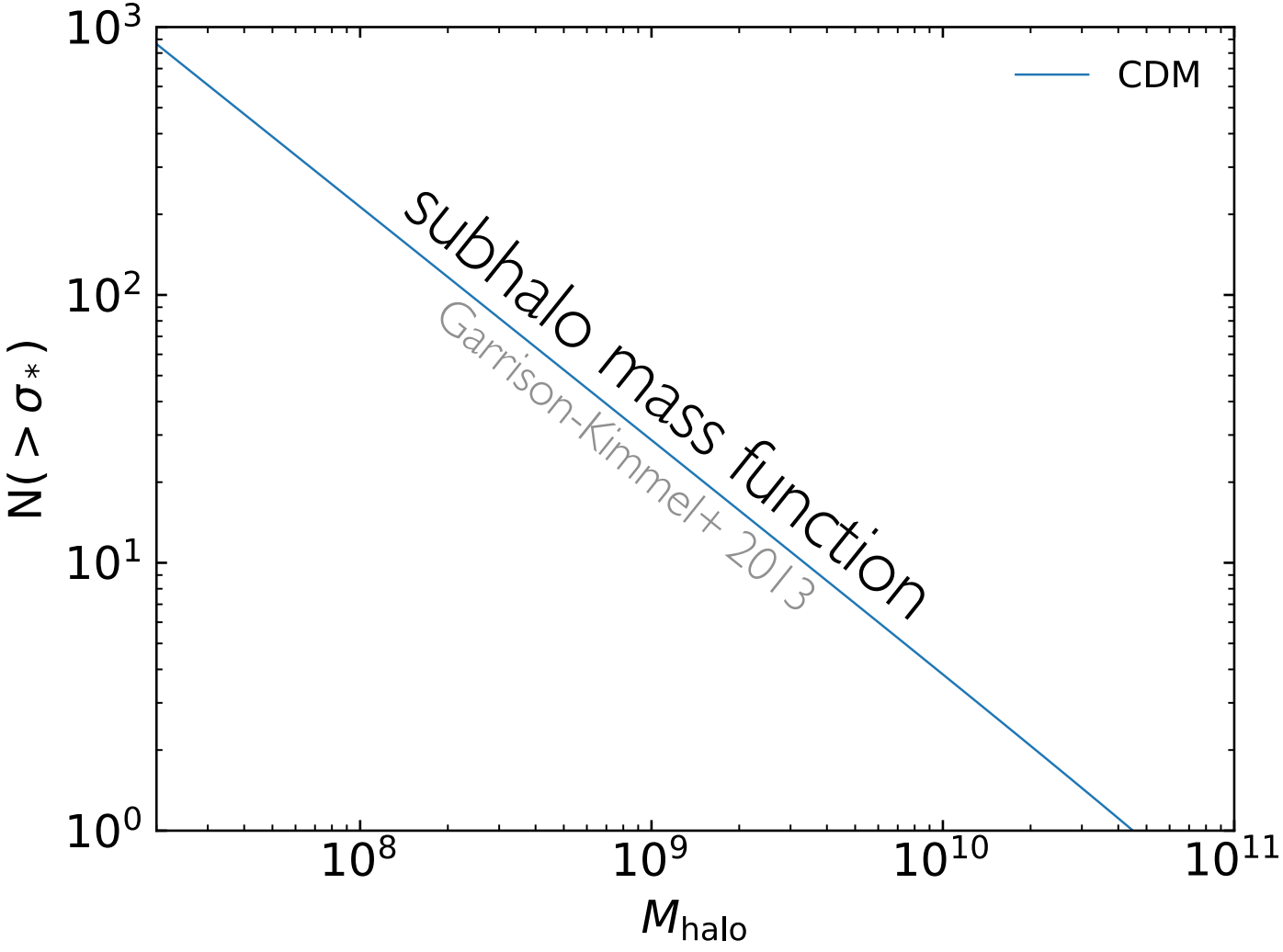
radial distributions



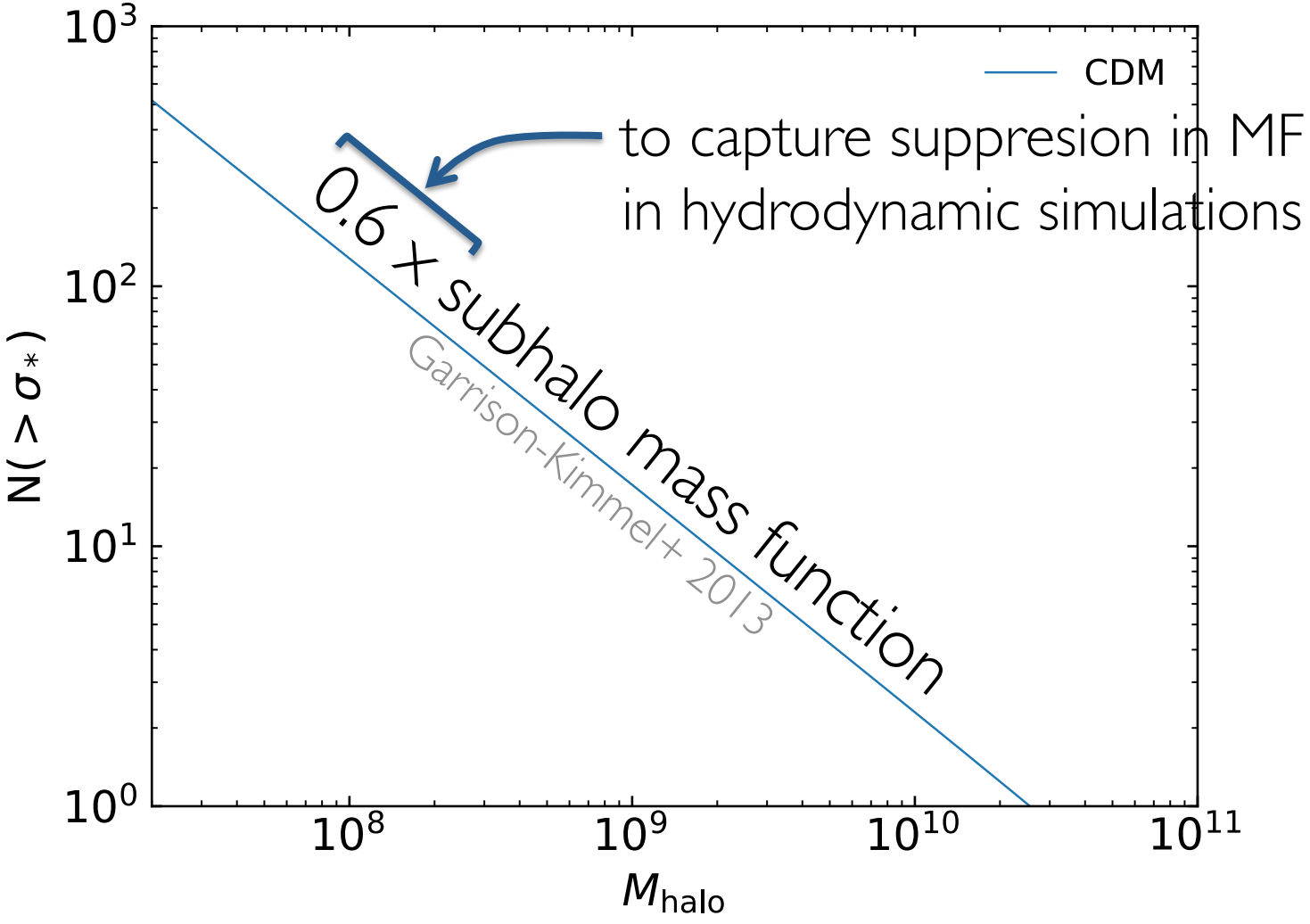
corrected velocity function



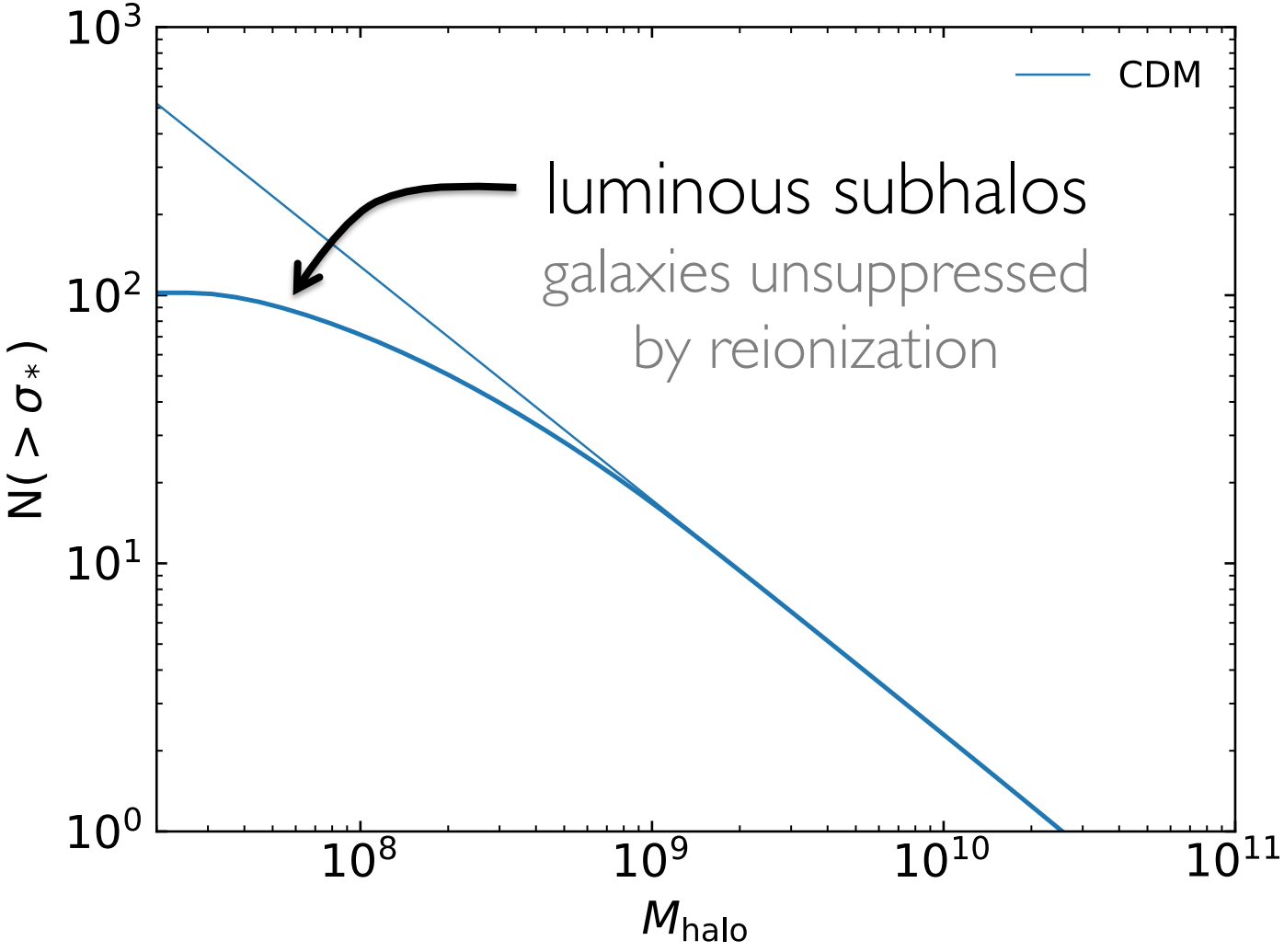
predictions from simulations



predictions from simulations

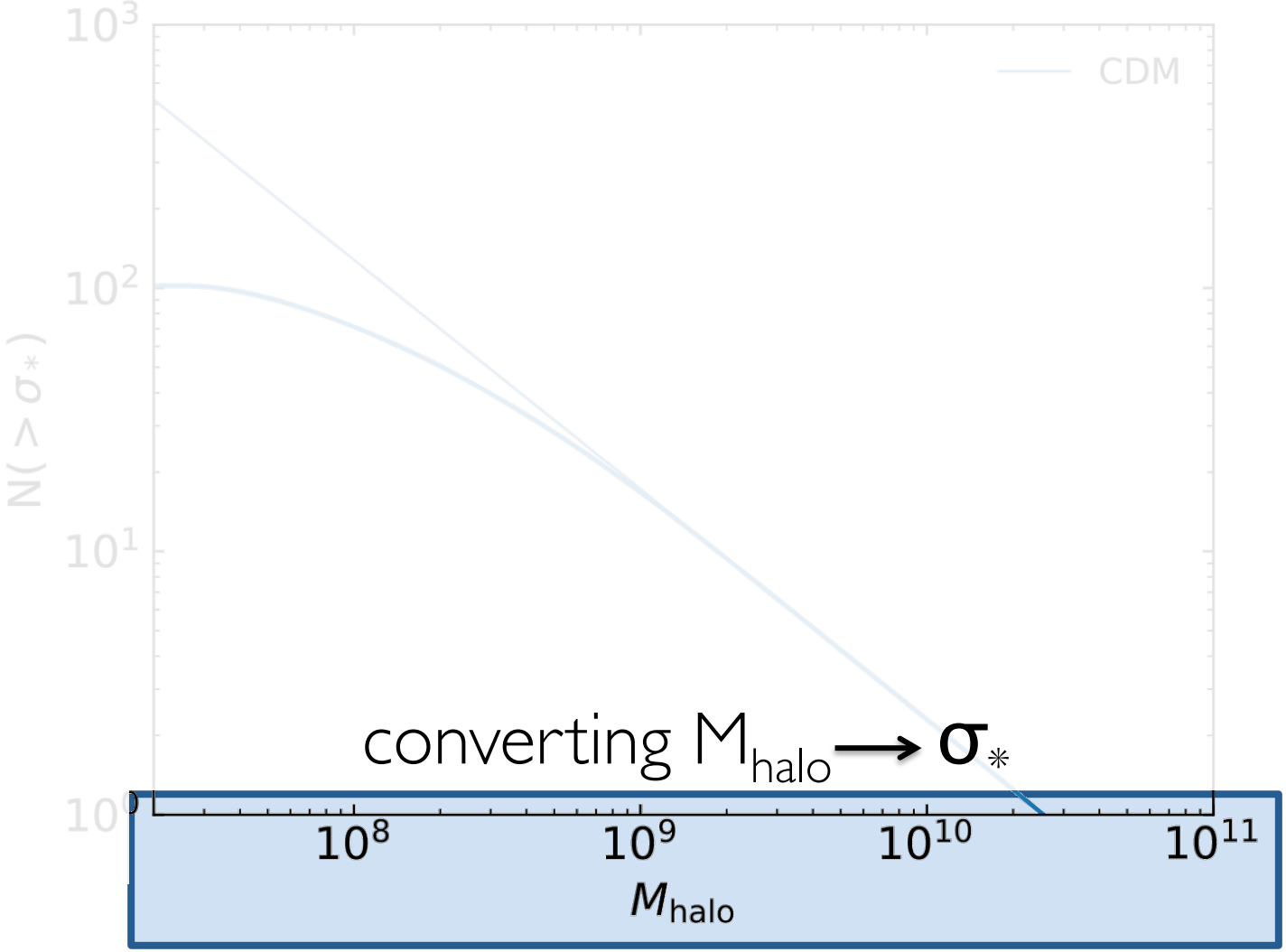


predictions from simulations



Dooley+ 2017, Barber+ 2014

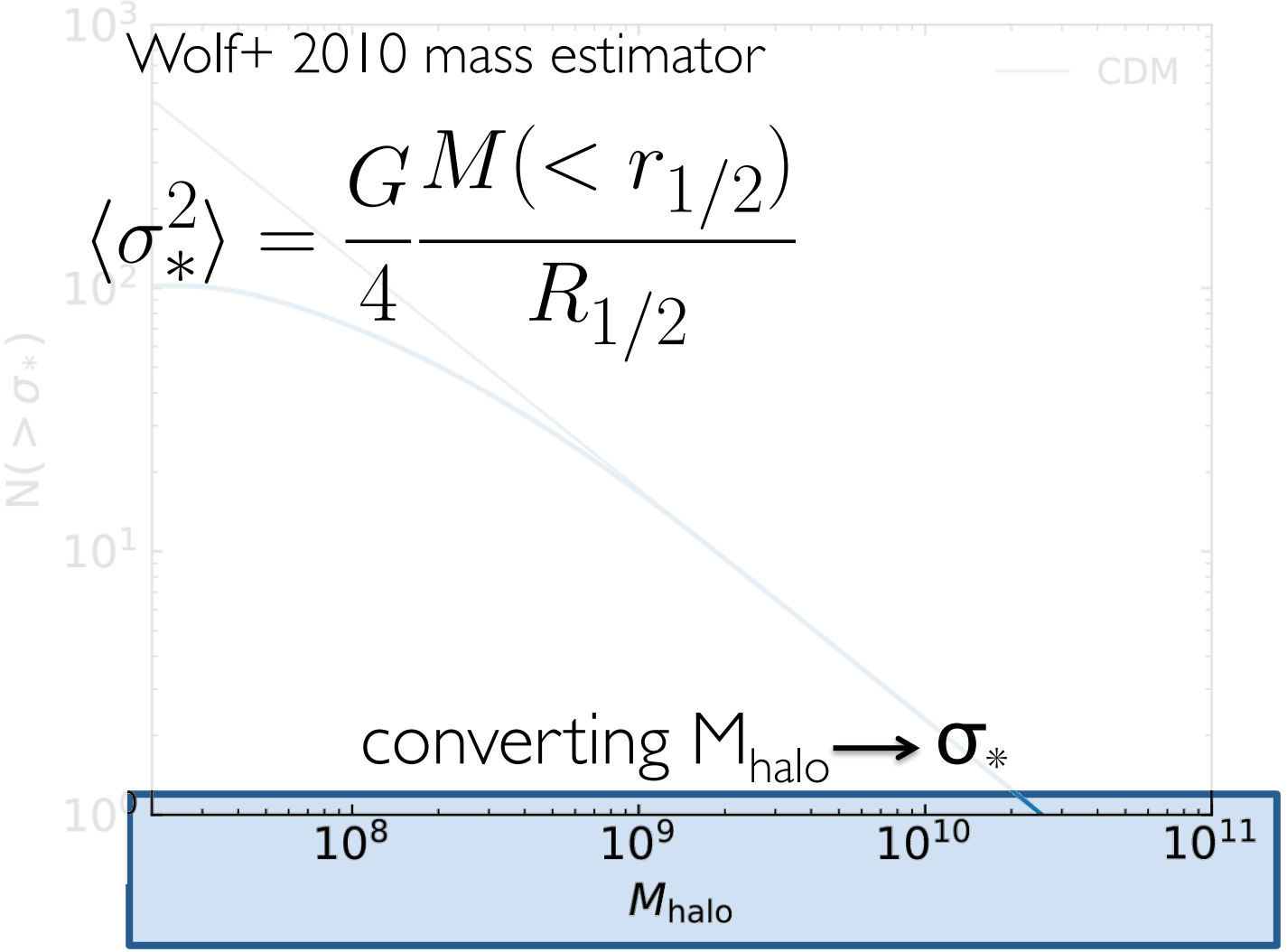
predictions from simulations



predictions from simulations

Wolf+ 2010 mass estimator

$$\langle \sigma_*^2 \rangle = \frac{G}{4} \frac{M(< r_{1/2})}{R_{1/2}}$$



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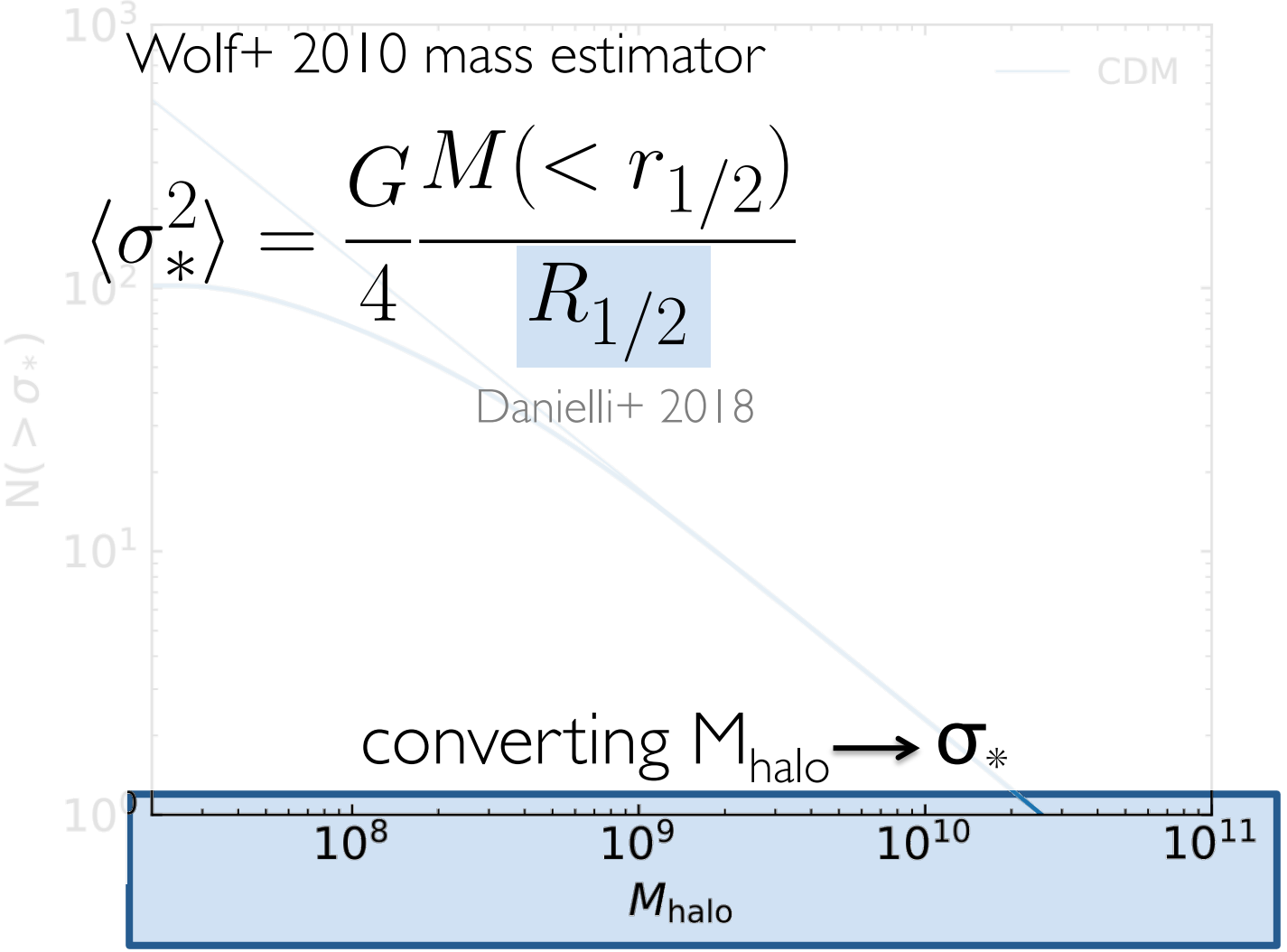
Danielli+ 2018



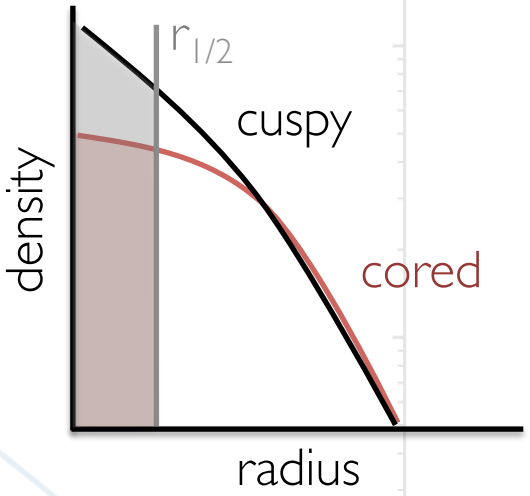
predictions from simulations

Wolf+ 2010 mass estimator

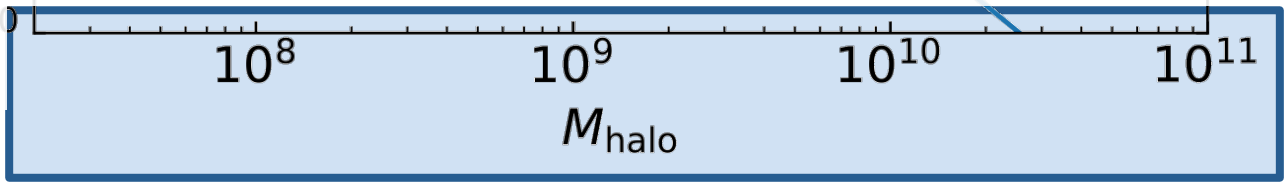
$$\langle \sigma_*^2 \rangle = \frac{G}{4} \frac{M(< r_{1/2})}{R_{1/2}}$$

Danielli+ 2018

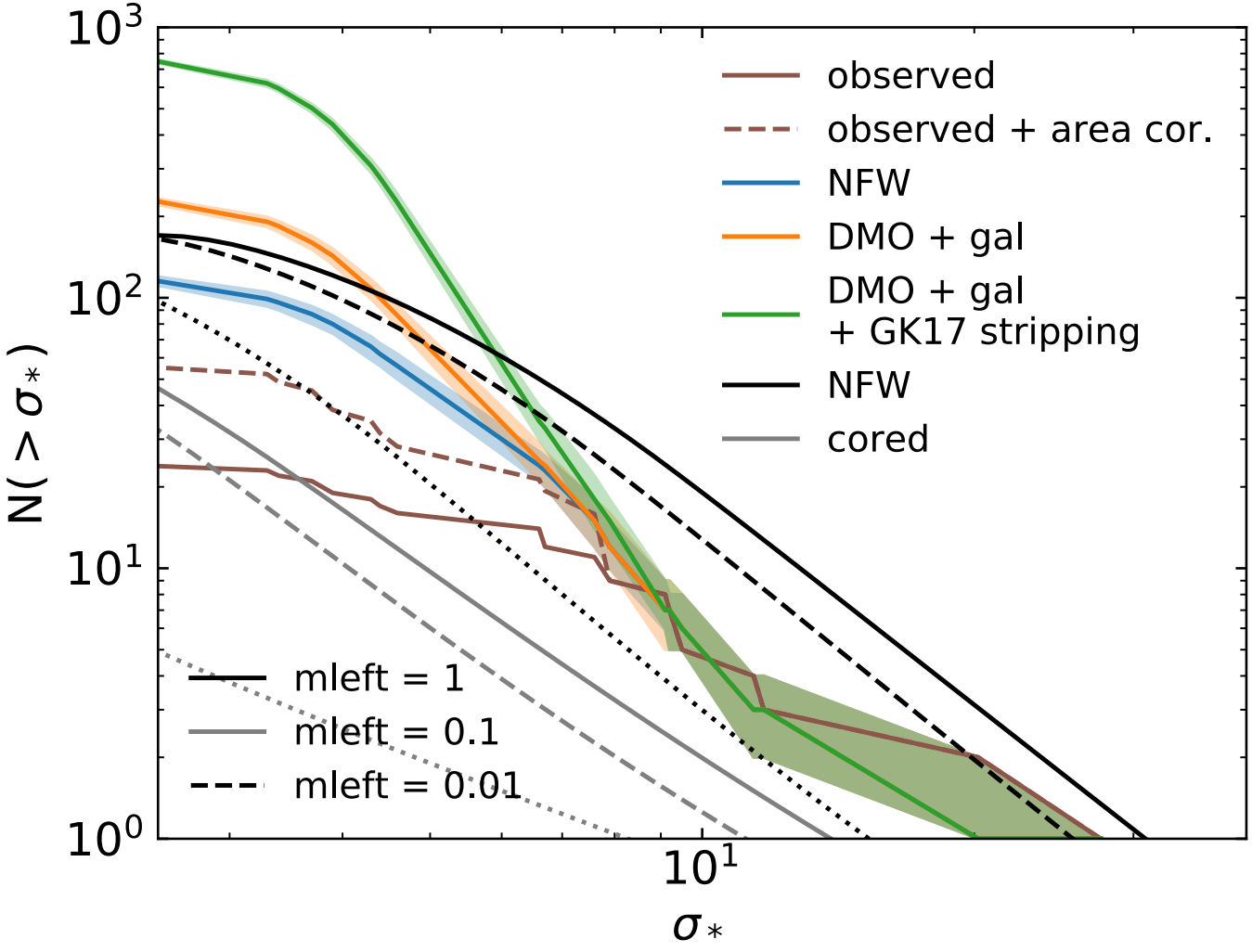
calculate for different density profiles



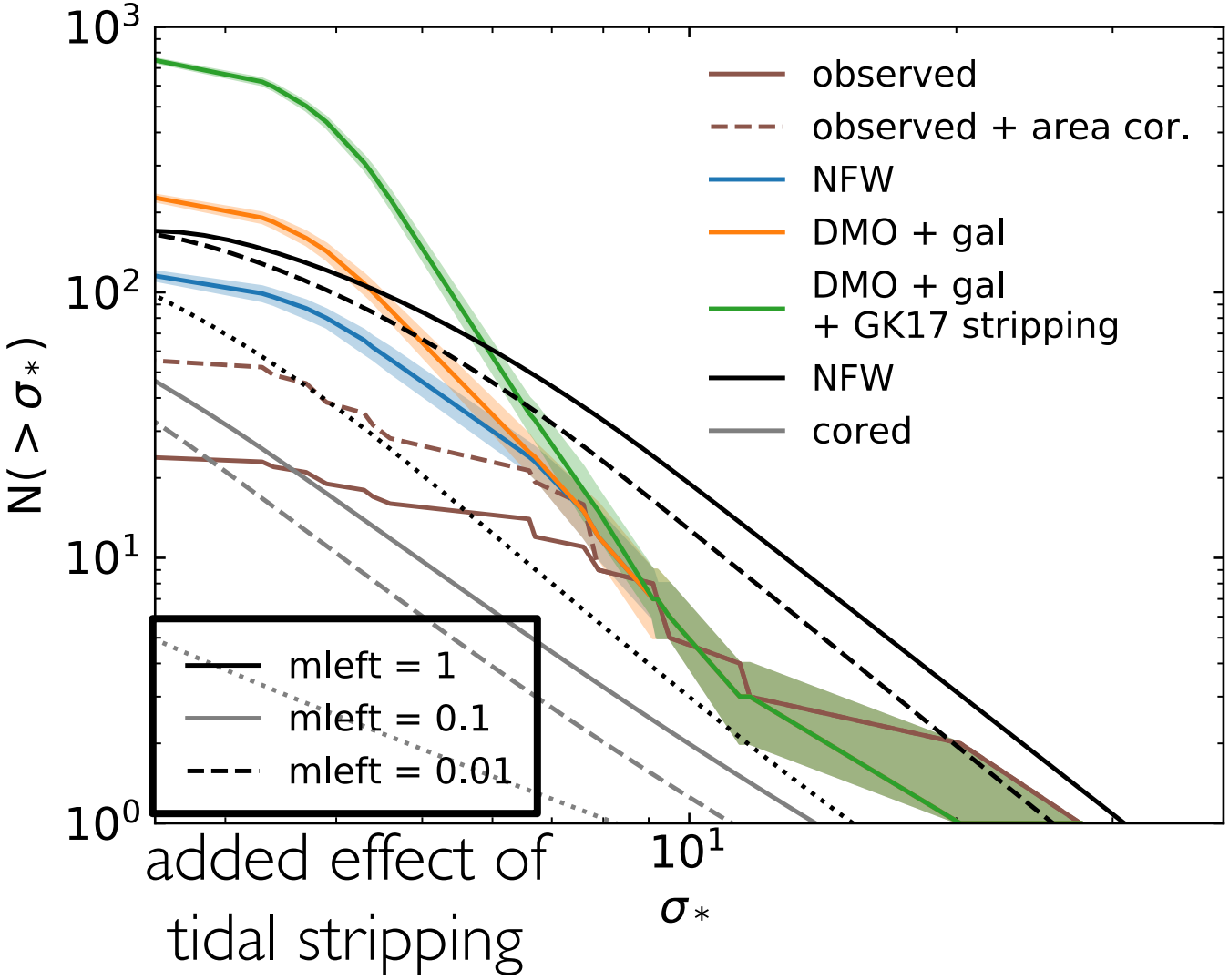
converting $M_{halo} \longrightarrow \sigma_*$



theory vs. observations

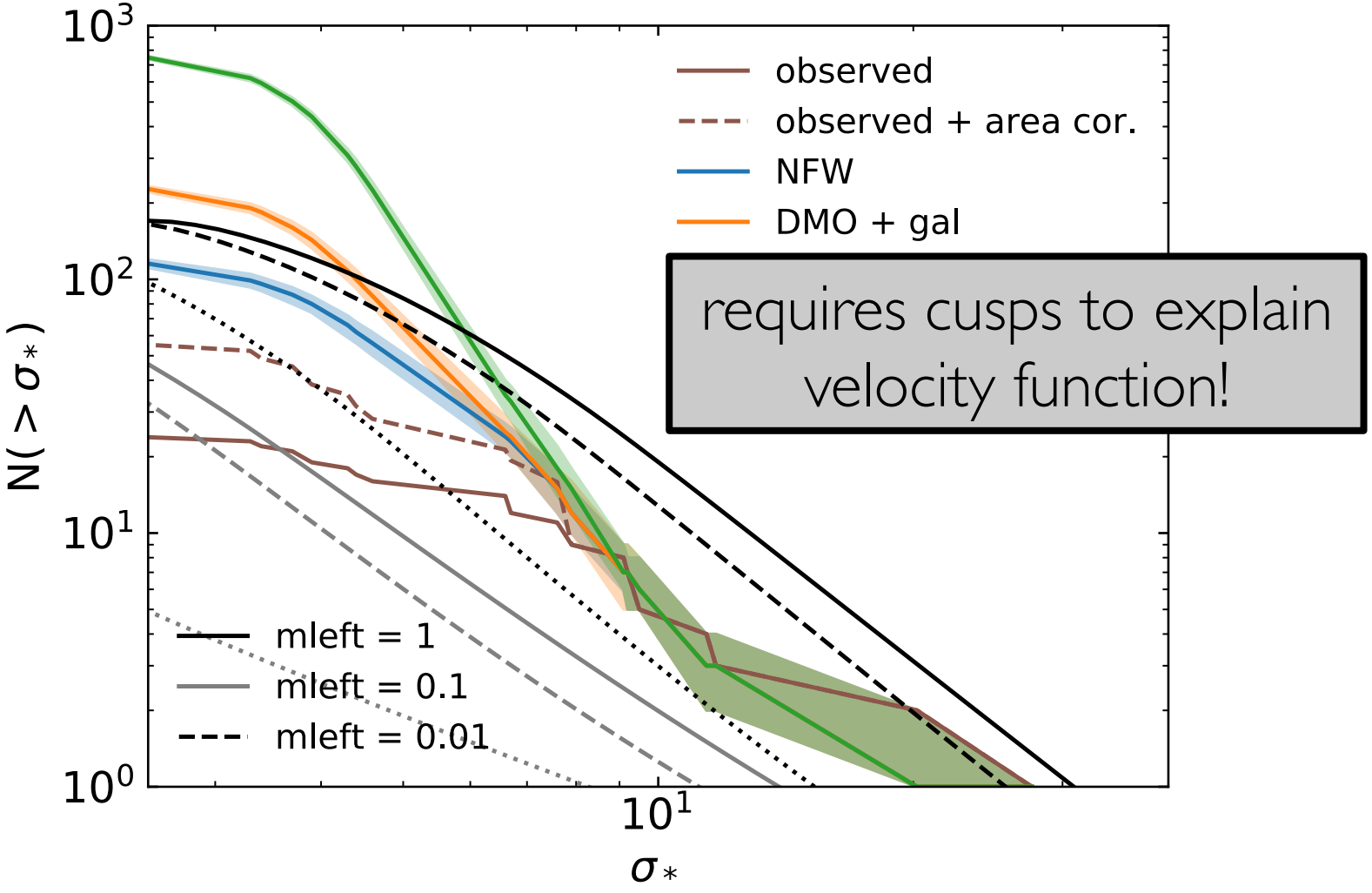


theory vs. observations



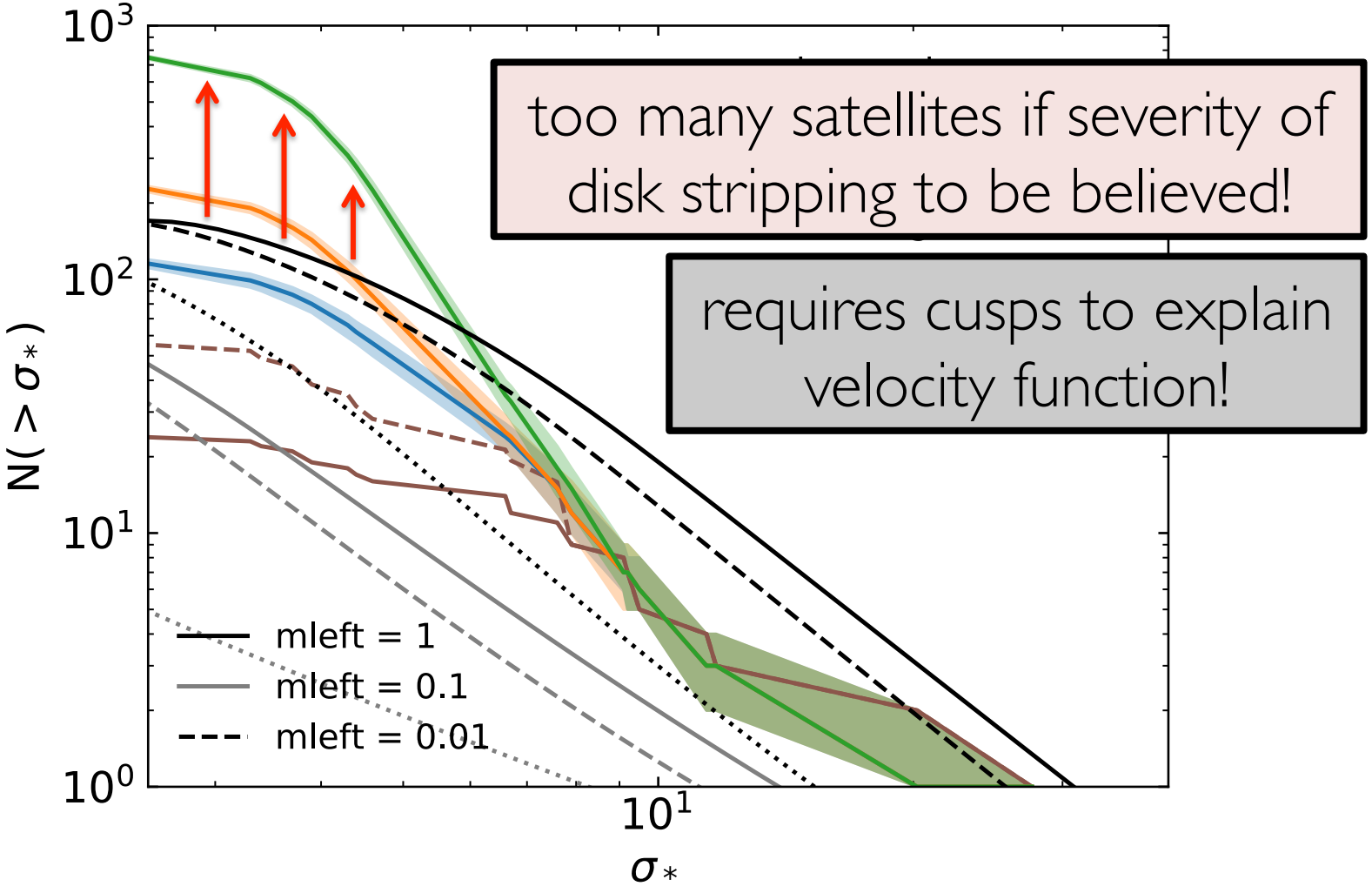
Penarrubia+ 2010

theory vs. observations

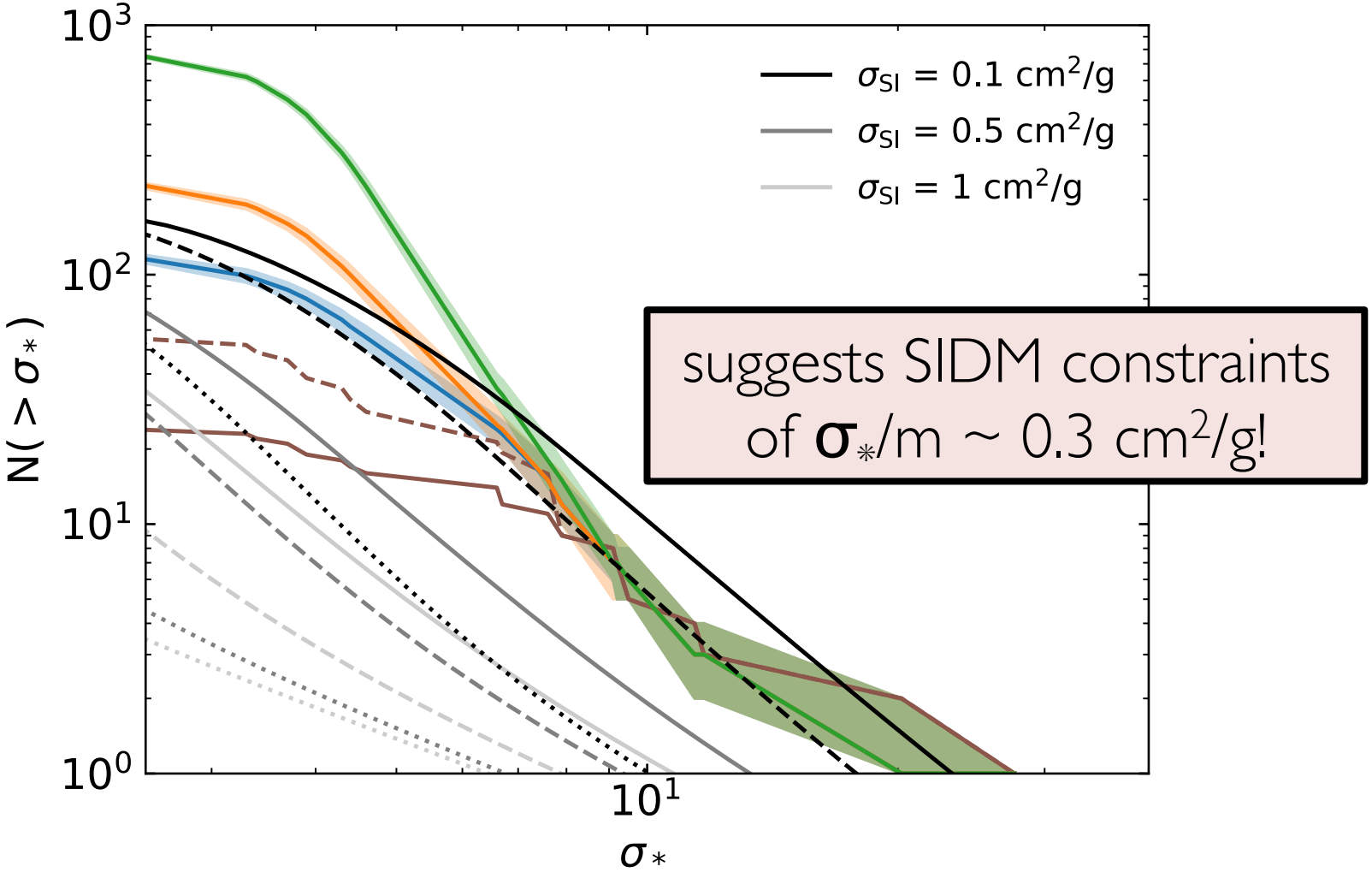


requires cusps to explain velocity function!

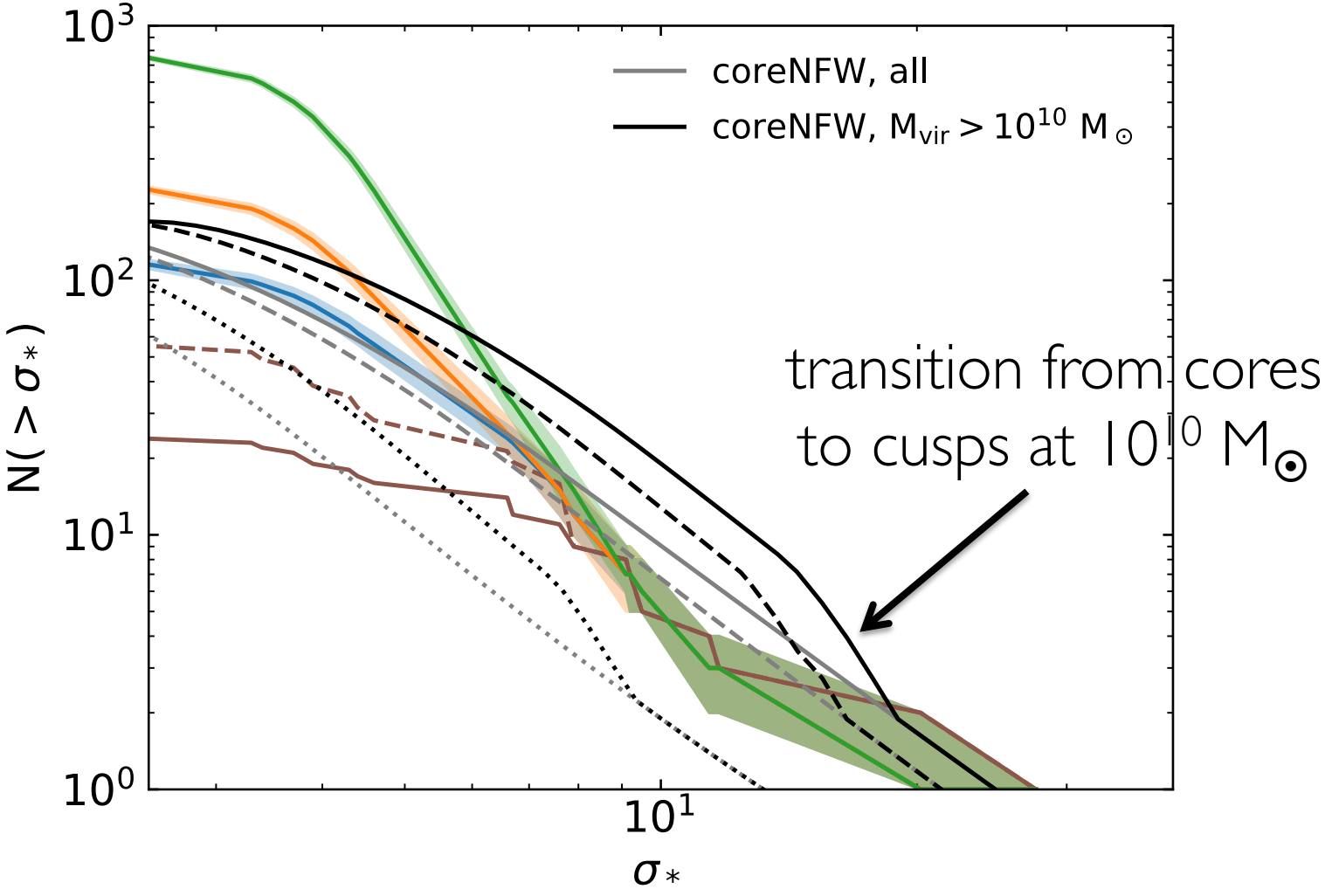
theory vs. observations



implications for SIDM

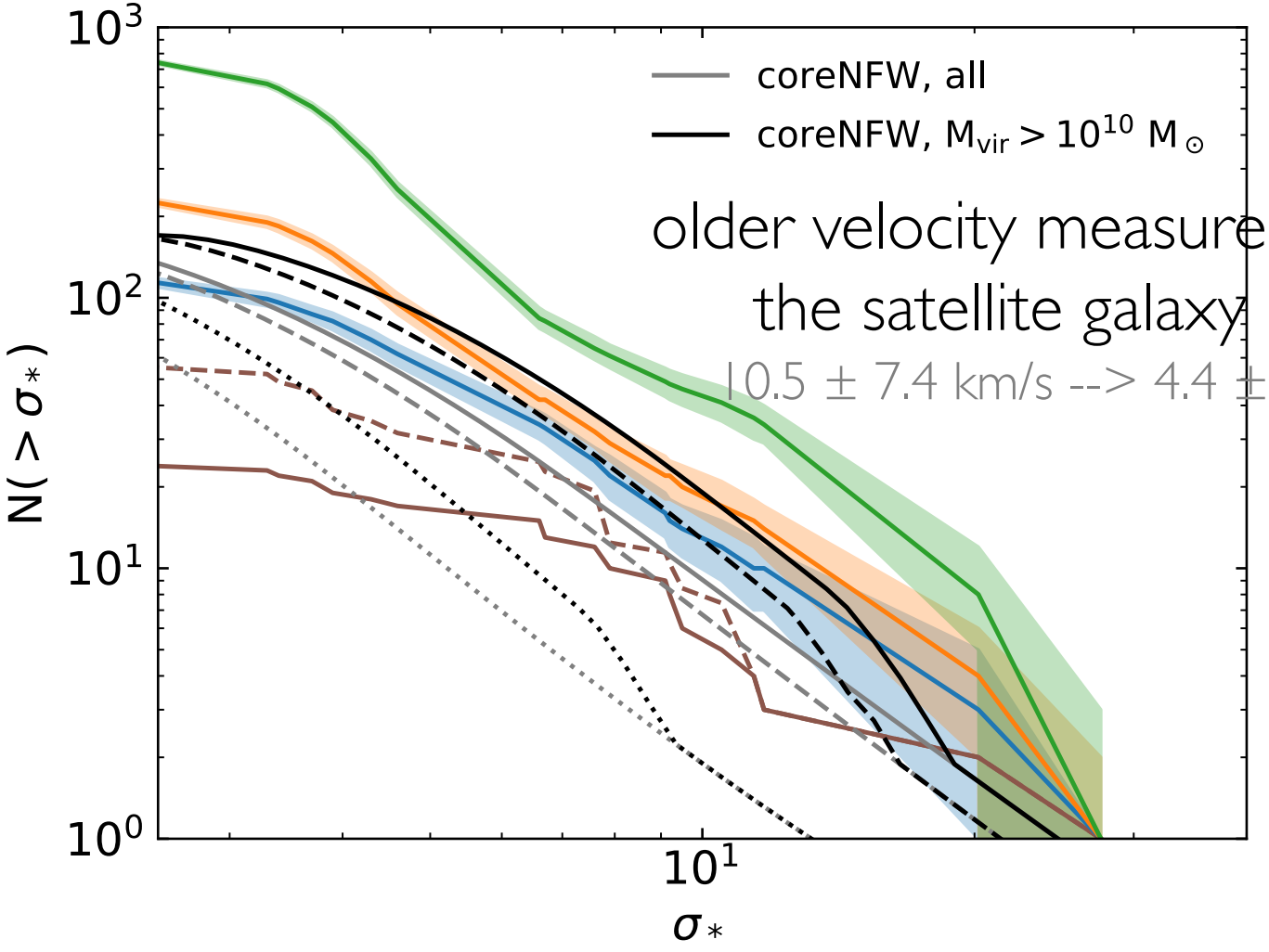


corrected velocity function



Read+2016, Robles+ 2017

observational uncertainties

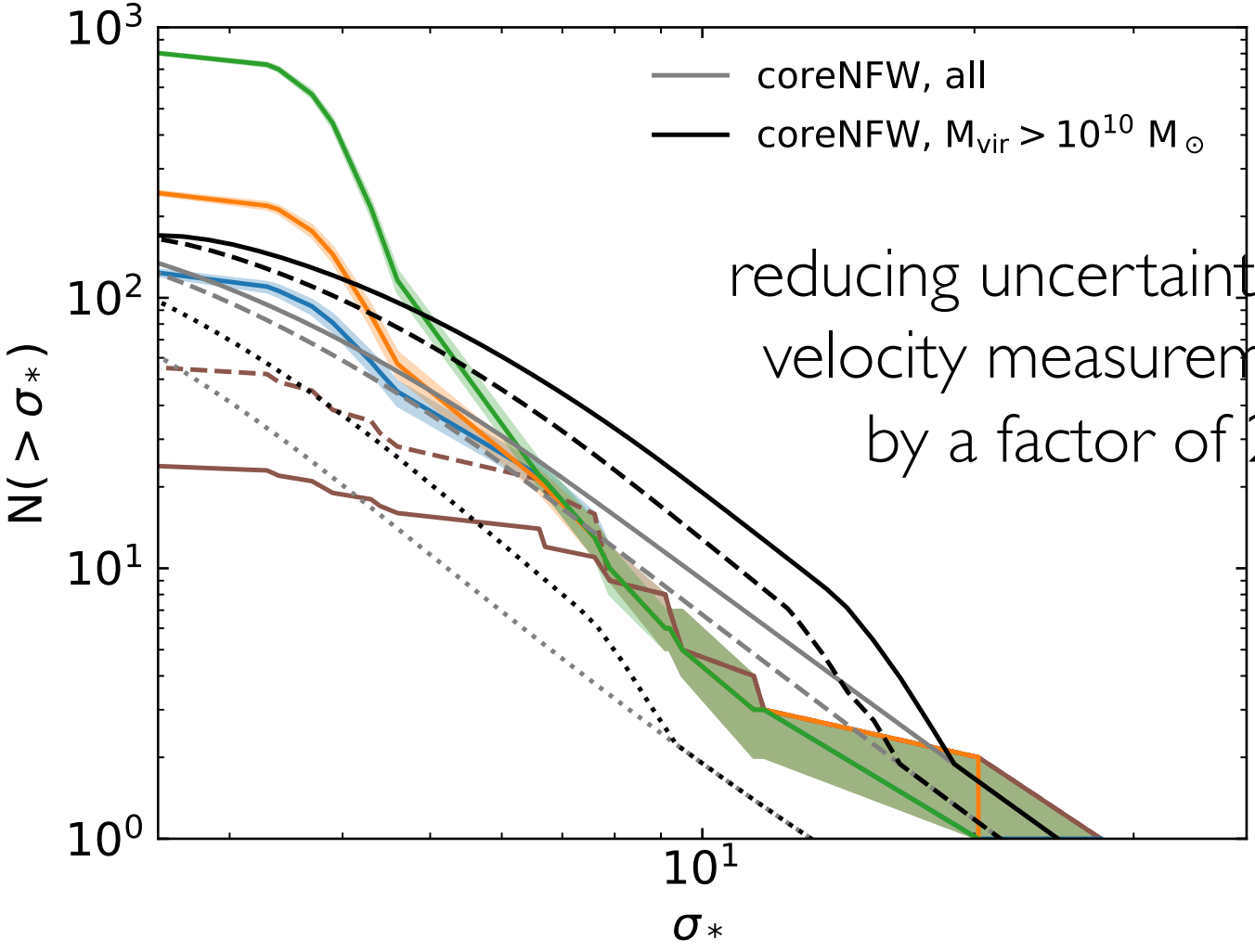


older velocity measurements for the satellite galaxy Boo II

10.5 ± 7.4 km/s --> 4.4 ± 1.1 km/s

Geha+, private communication

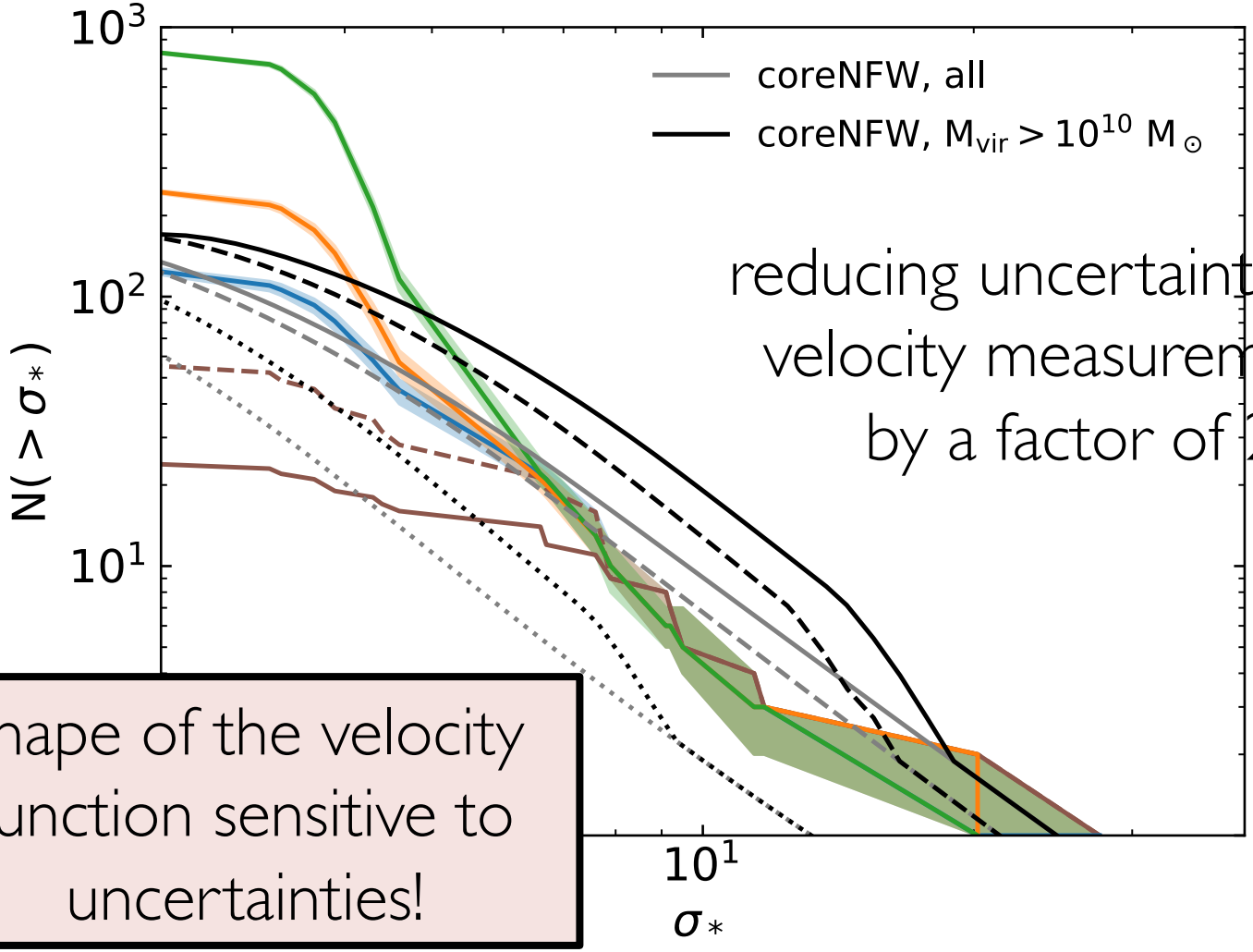
observational uncertainties



reducing uncertainties on velocity measurements by a factor of 2

Geha+, private communication

observational uncertainties



reducing uncertainties on velocity measurements by a factor of 2

shape of the velocity function sensitive to uncertainties!

Geha+, private communication

velocity functions: a summary

CDM with baryons does a decent job explaining satellite kinematics

but too many satellites with disk stripping

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SIDM with $\sigma_*/m > 0.3$ cm^2/g disfavored

velocity functions: a summary

CDM with baryons does a decent job explaining satellite kinematics

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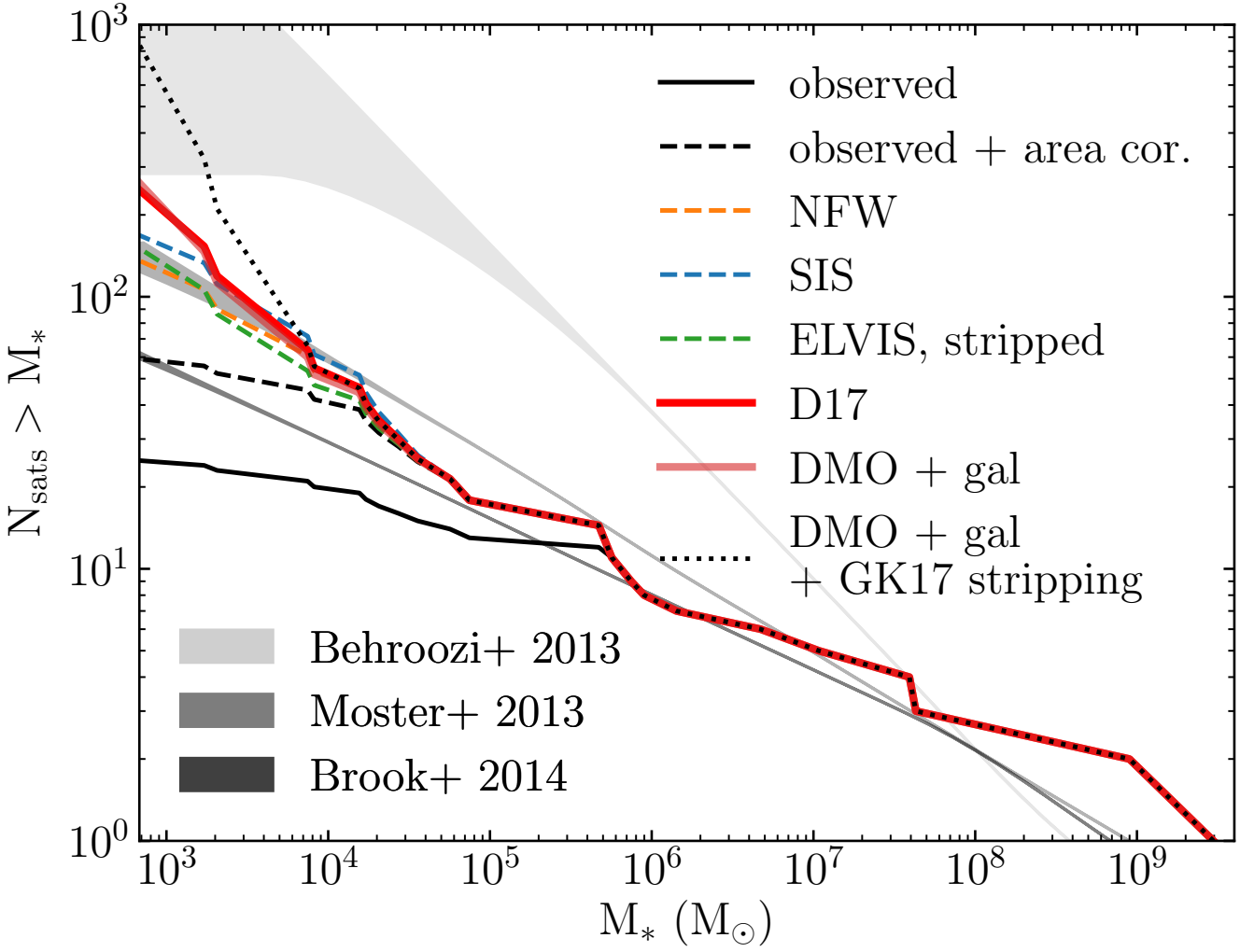
SIDM with $\sigma_*/m > 0.3$ cm^2/g disfavored

shape of corrected velocity function strongly dependent velocity uncertainties

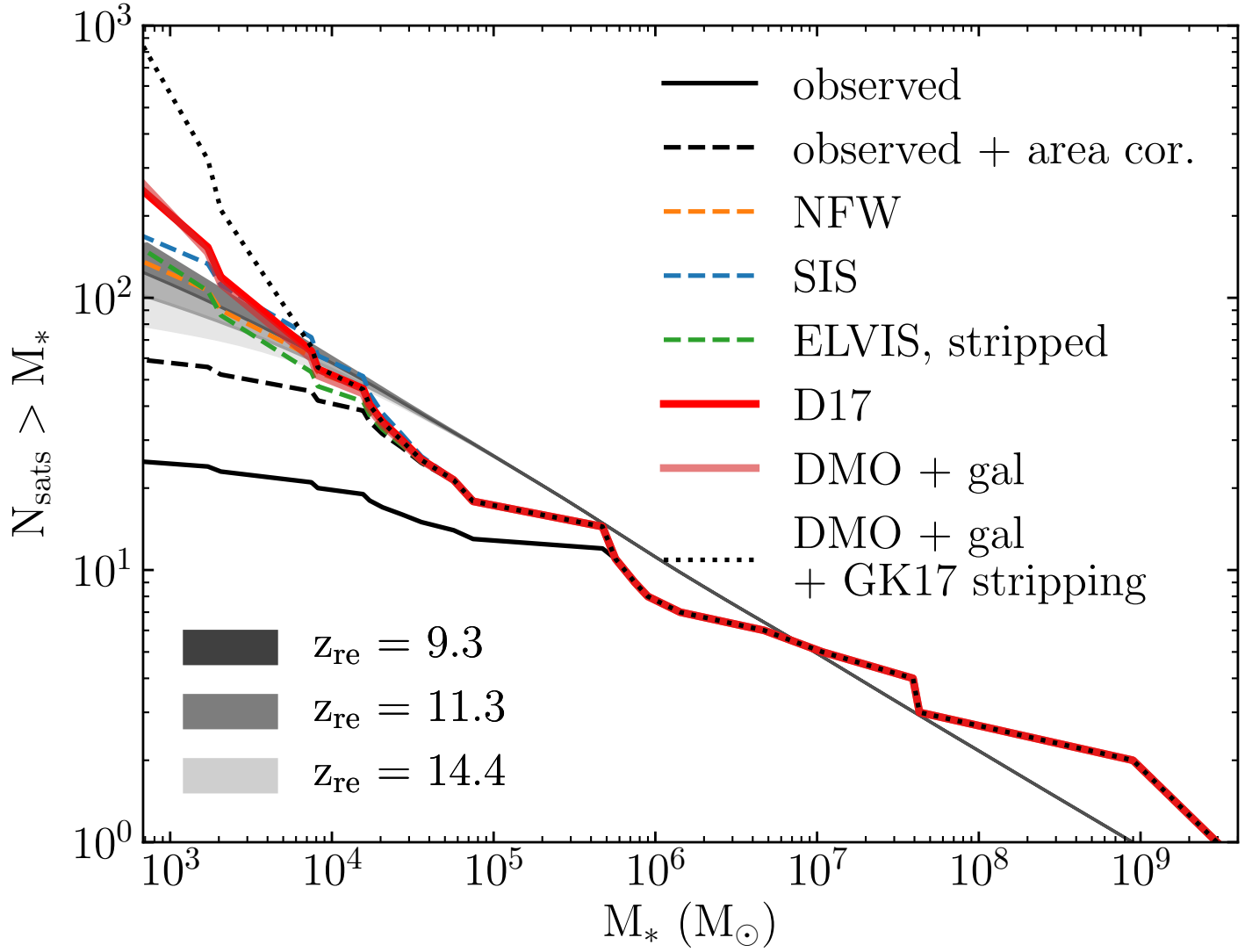
more precise measurements needed!

EXTRAS: MSP

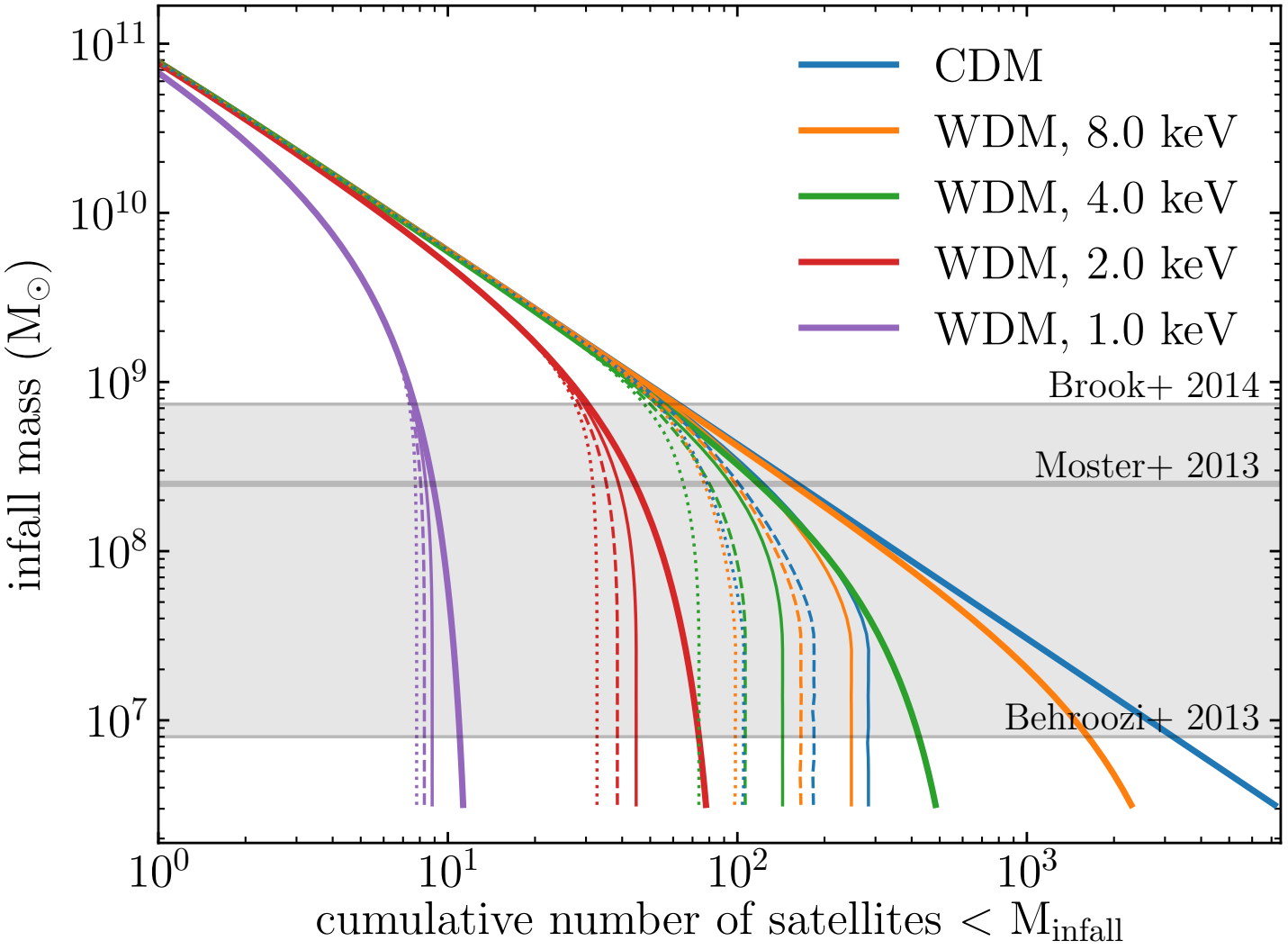
corrected luminosity function



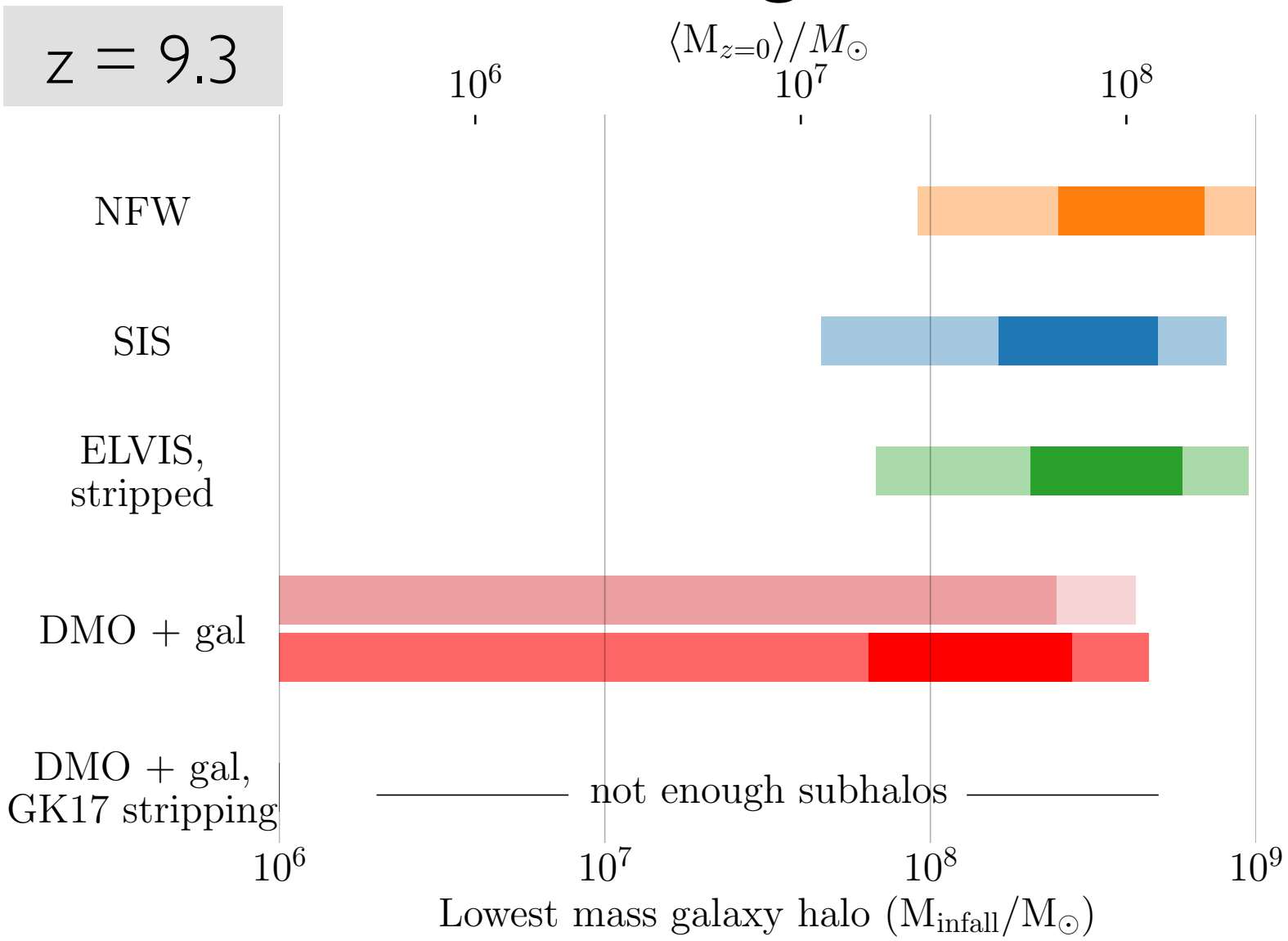
corrected luminosity function



dependence on reionization redshift

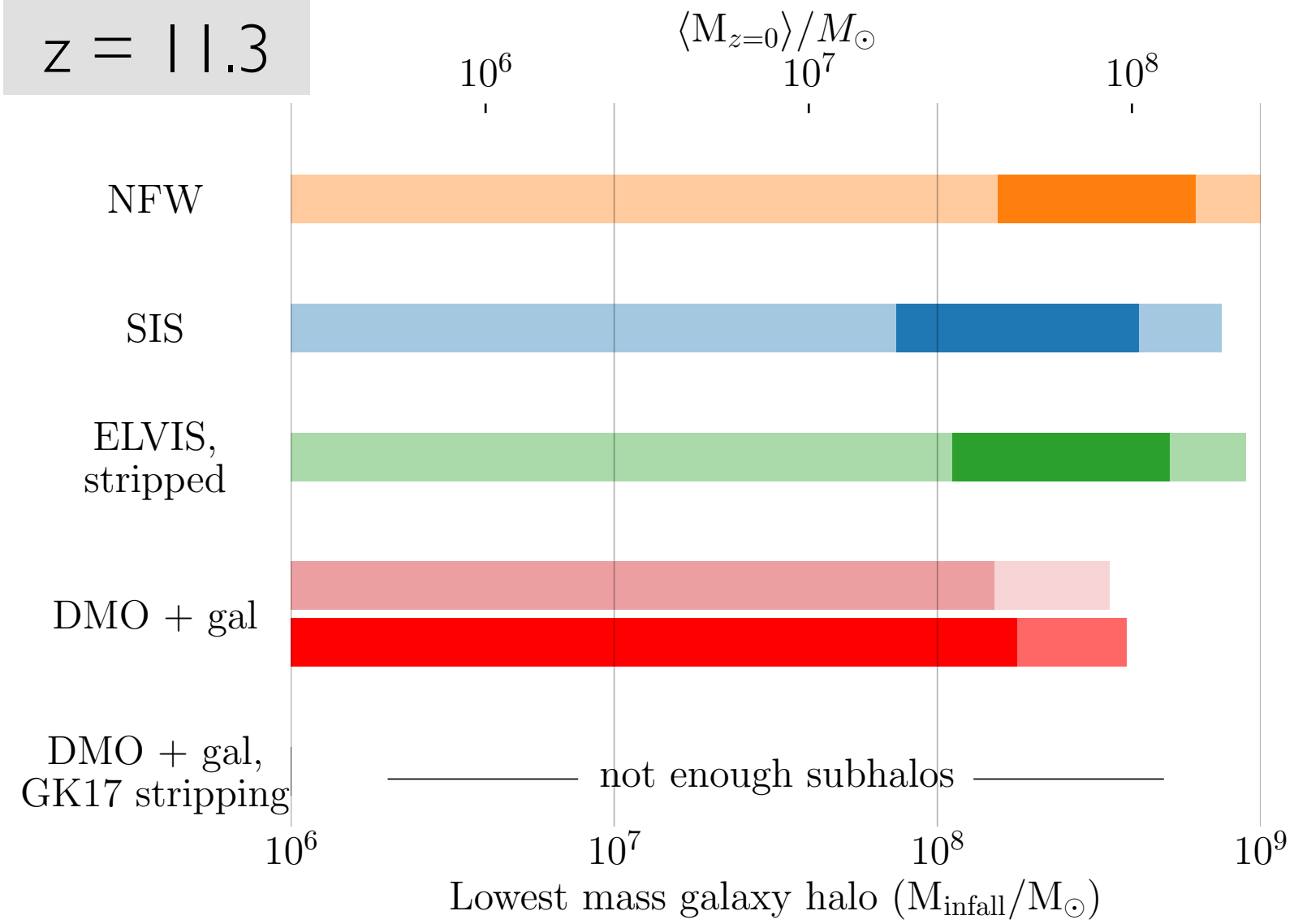


mass of Segue I



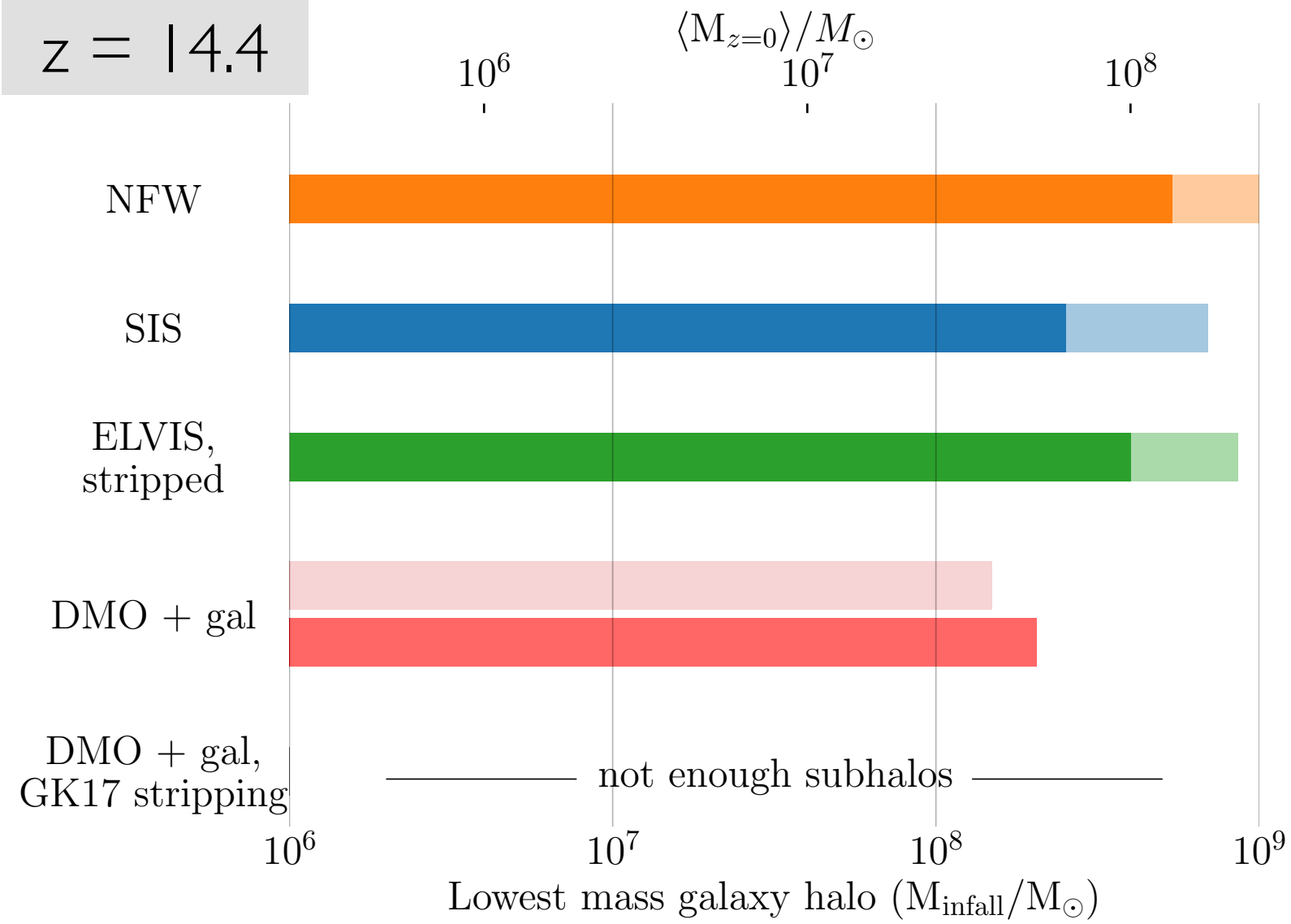
mass of Segue I

z = 11.3



mass of Segue I

z = 14.4



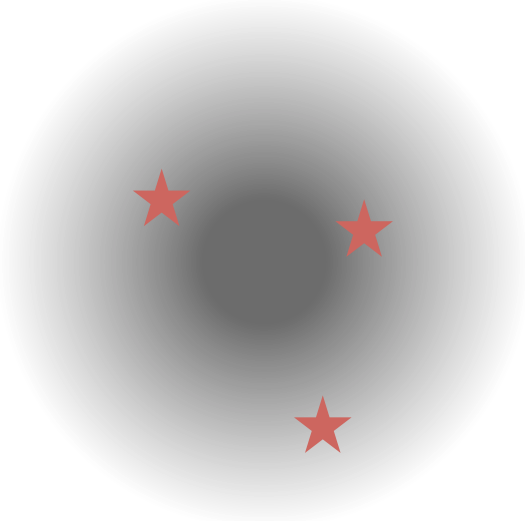
velocity dispersions, σ_*

less massive subhalo

more massive subhalo

velocity dispersions, σ_*

less massive subhalo



more massive subhalo

velocity dispersions, σ_*

less massive subhalo

more massive subhalo

Stars in more massive subhalos orbit faster
(to counteract gravity), thus velocities a proxy for mass!

velocity dispersions, σ_*

less massive subhalo

more massive subhalo

Stars in more massive subhalos orbit faster
(to counteract gravity), thus velocities a proxy for central mass!

Stars typically live in the centers of subhalos, and thus are sensitive to the presence of central cores vs. cups!