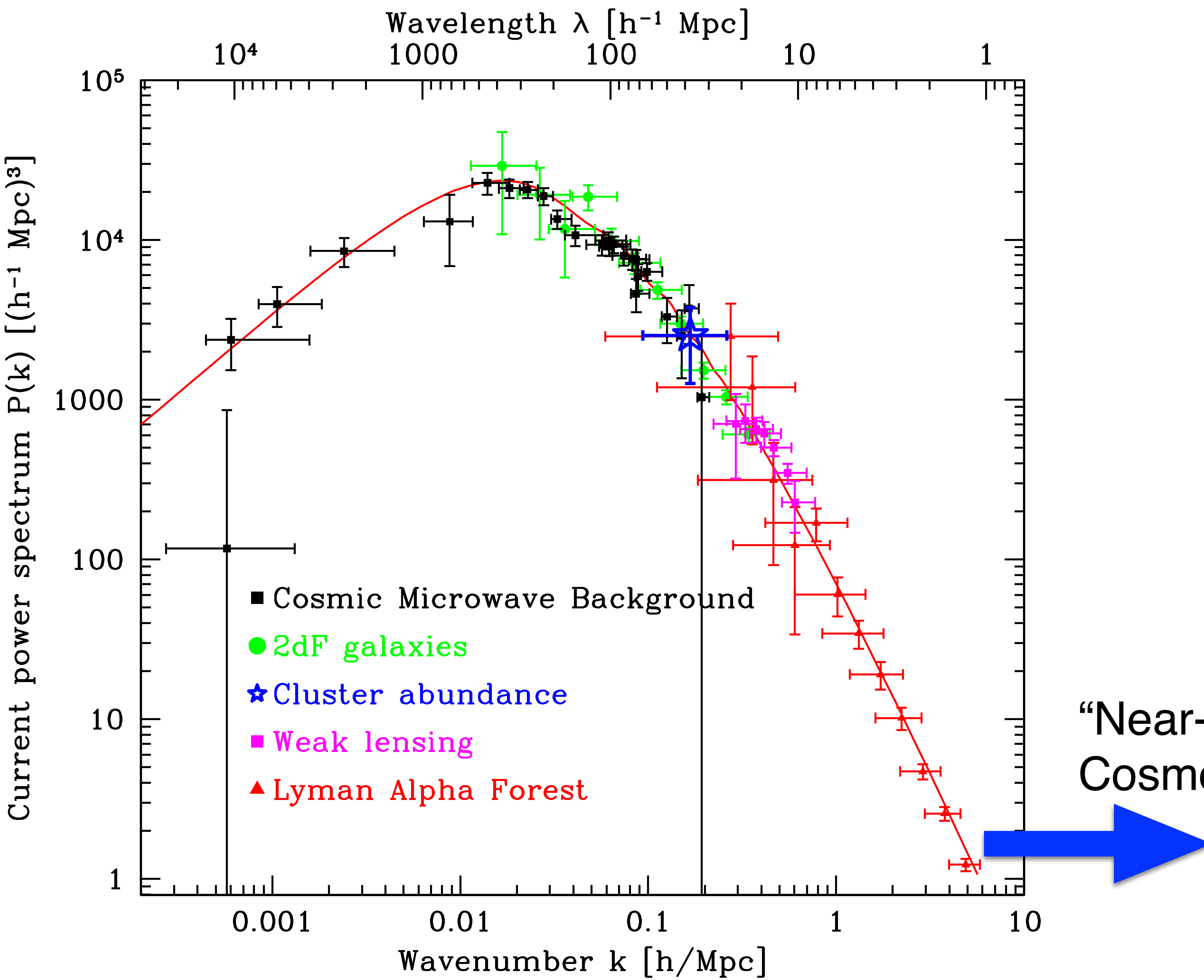
Solving the cusp-core problem in dwarf galaxies

Justin I. Read
Matthew Walker, Pascal Steger, Oscar Agertz, Michelle Collins, Denis Erkal, Giuliano Iorio, Filippo Fraternali, Alexandra Gregory
UNIVERSITY OF SURREY

The Standard Cosmological Model

The standard cosmological model



"Near-field" Cosmology

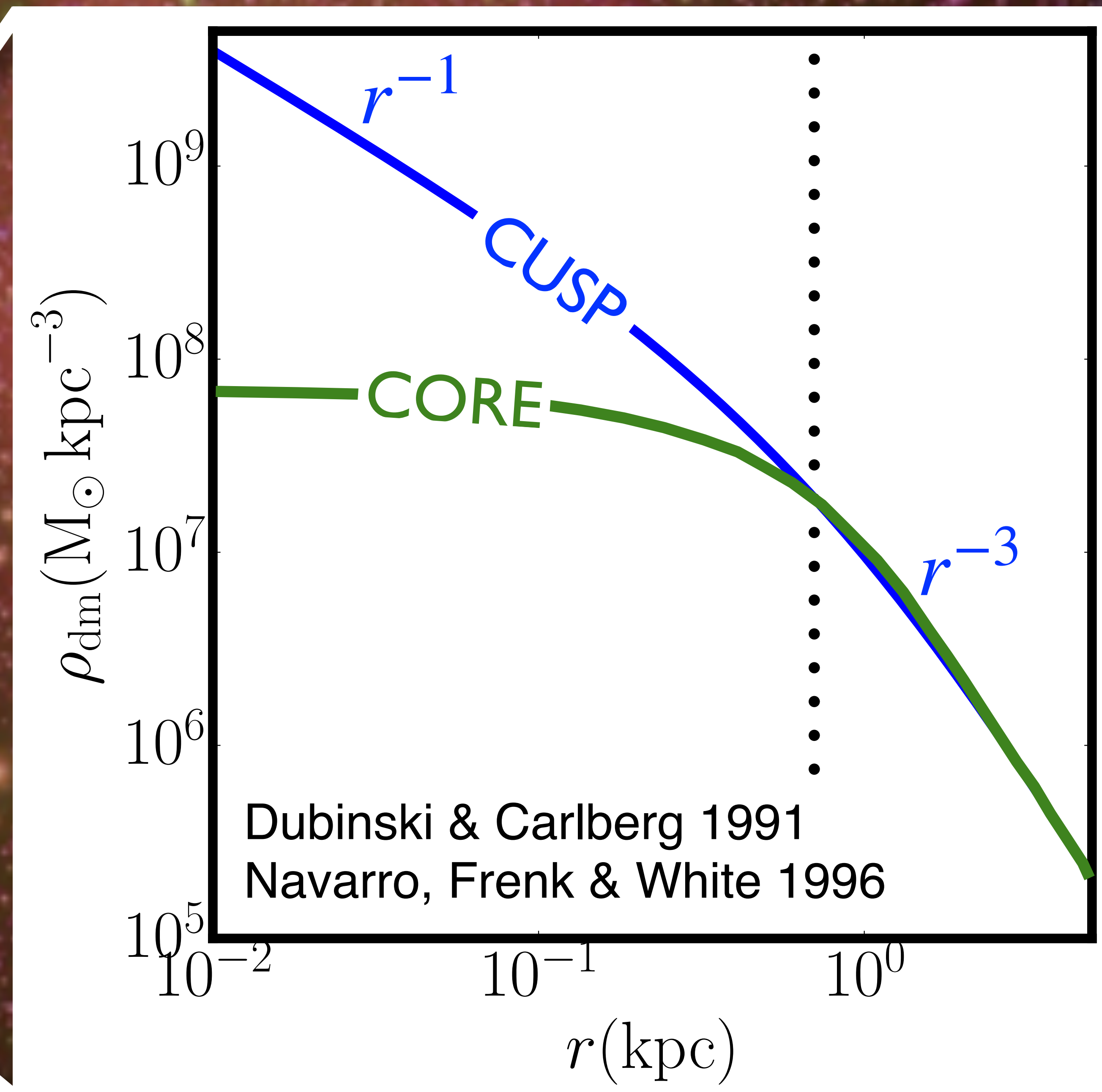
Tegmark & Zaldarriaga 2002

Small scale puzzles

"Aquarius" pure dark matter simulation of structure formation in an LCDM cosmology [Springel et al. 2008]

The cusp-core problem

[Flores et al. 1994; Moore 1994]



Volker Springel
Max-Planck-Institute
for Astrophysics

Pure Dark Matter Simulations

Observed Universe

Dark Matter Heating

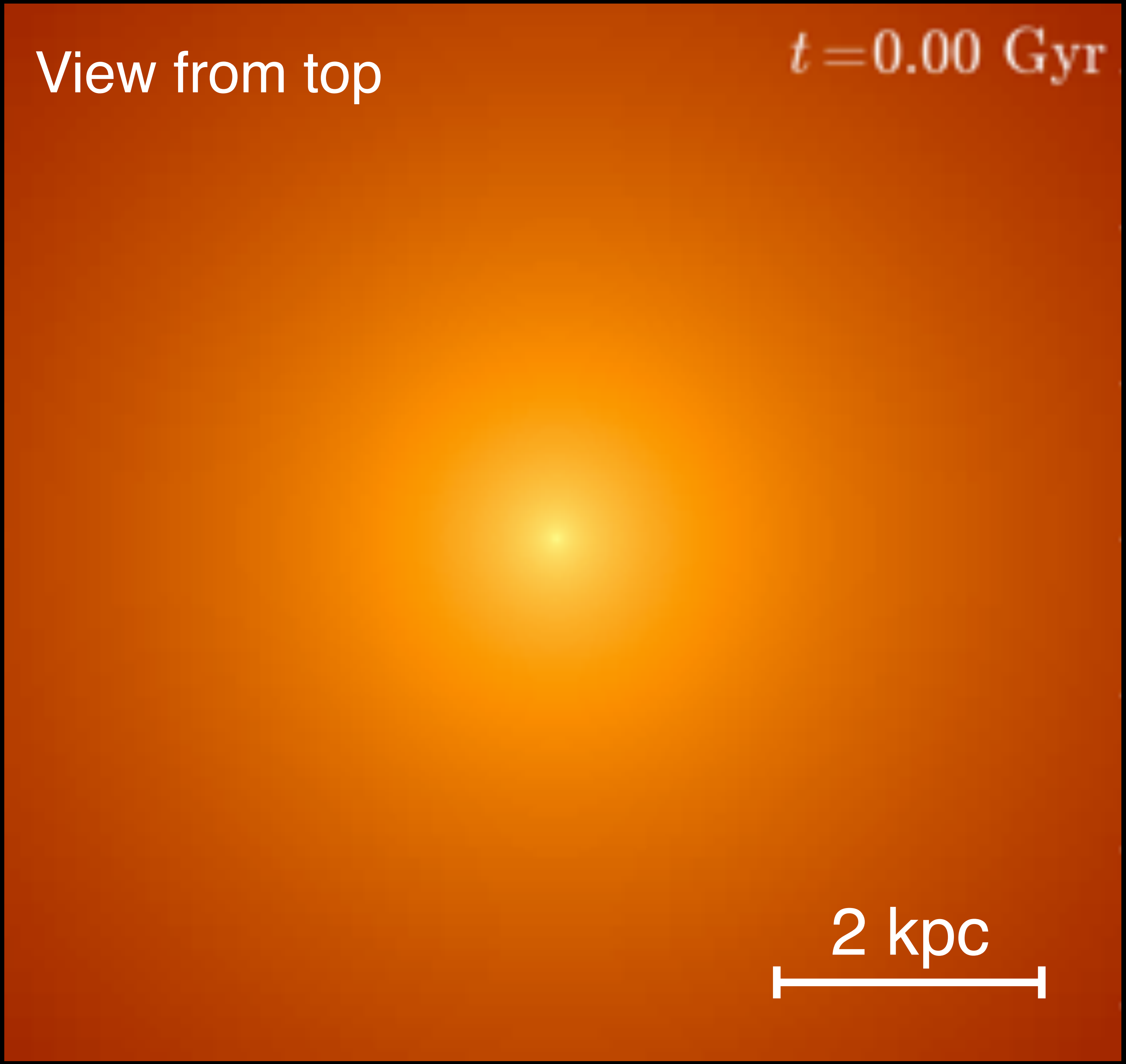
Dark matter heating

$\Delta x = 4\,\mathrm{pc}$

$M_{\rm res} = 300\,\mathrm{M}_\odot$

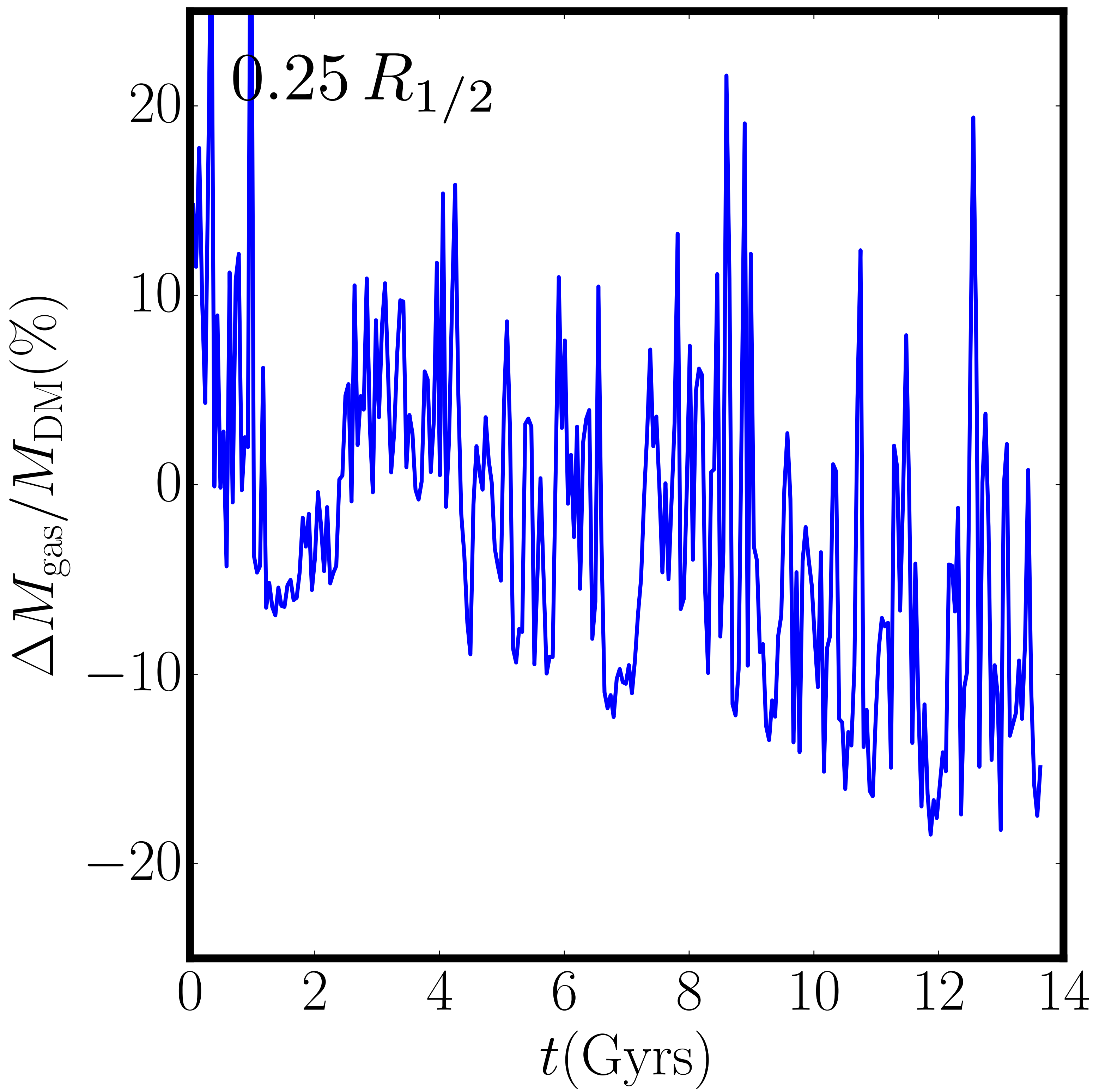
$\rho_{\rm th} = 300\,\mathrm{atoms/cc}$

$T_{\rm gas,min} = 10\,\mathrm{K}$



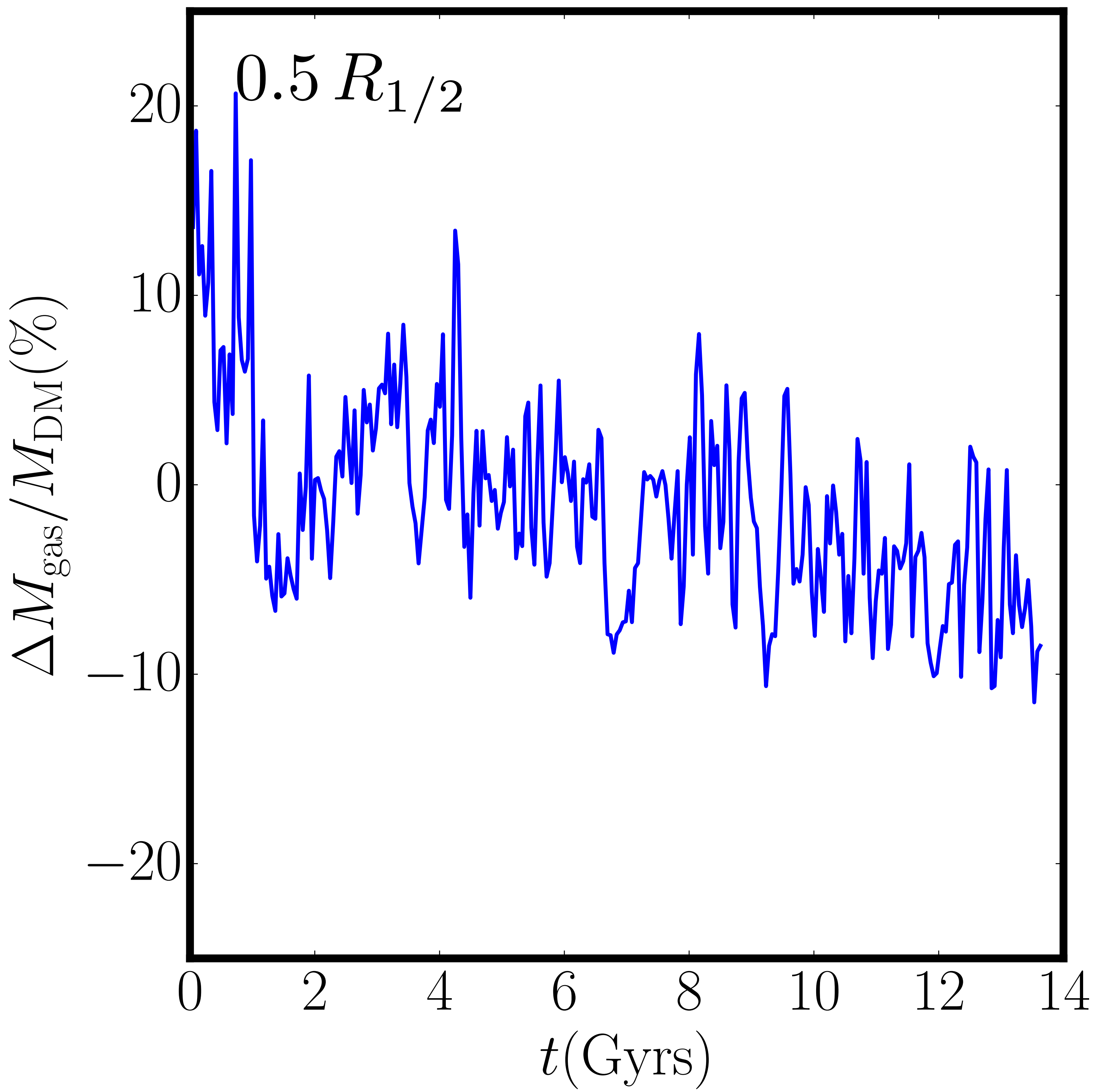
Read et al. 2016

Dark matter heating



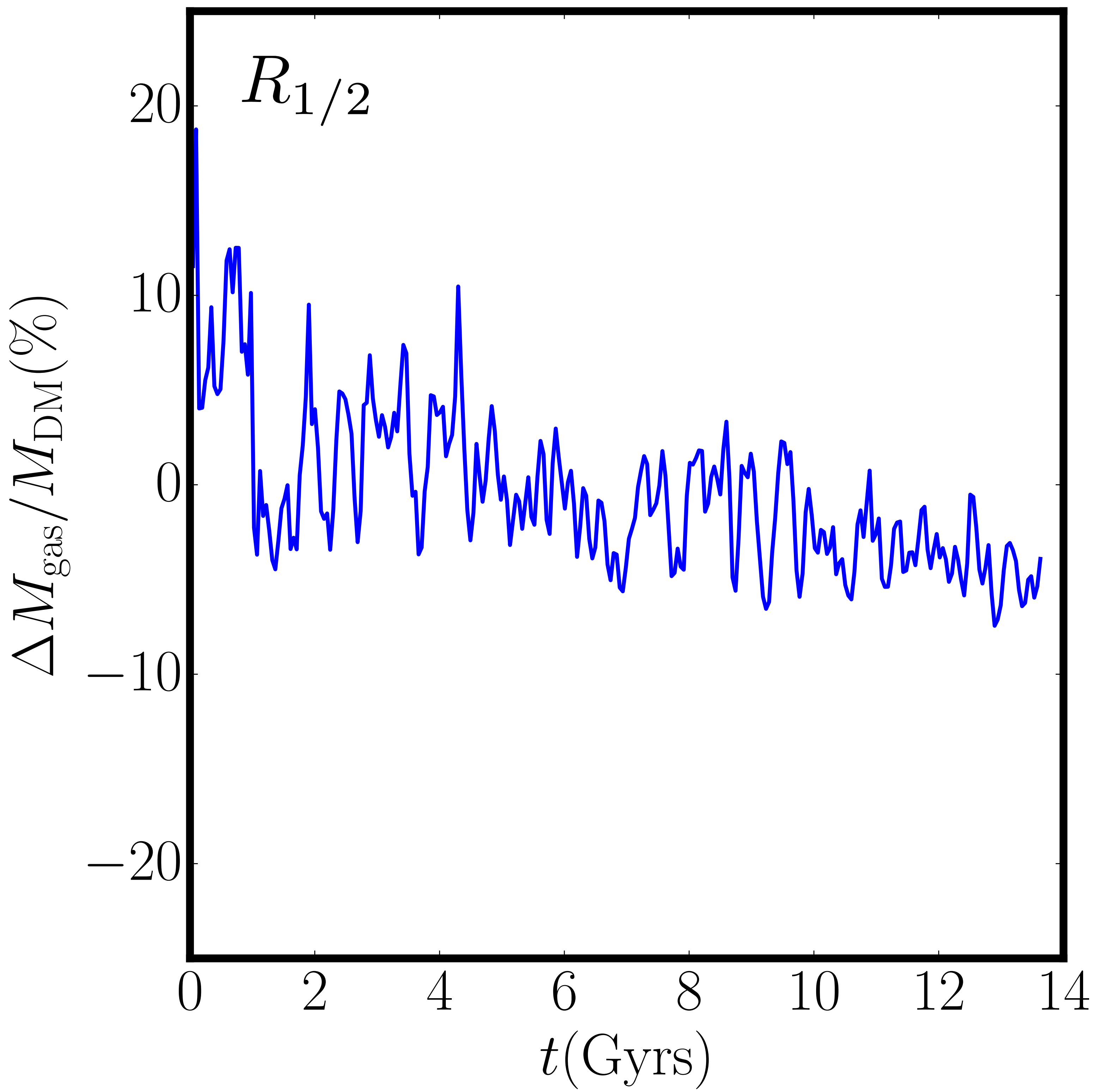
Read et al. 2016

Dark matter heating



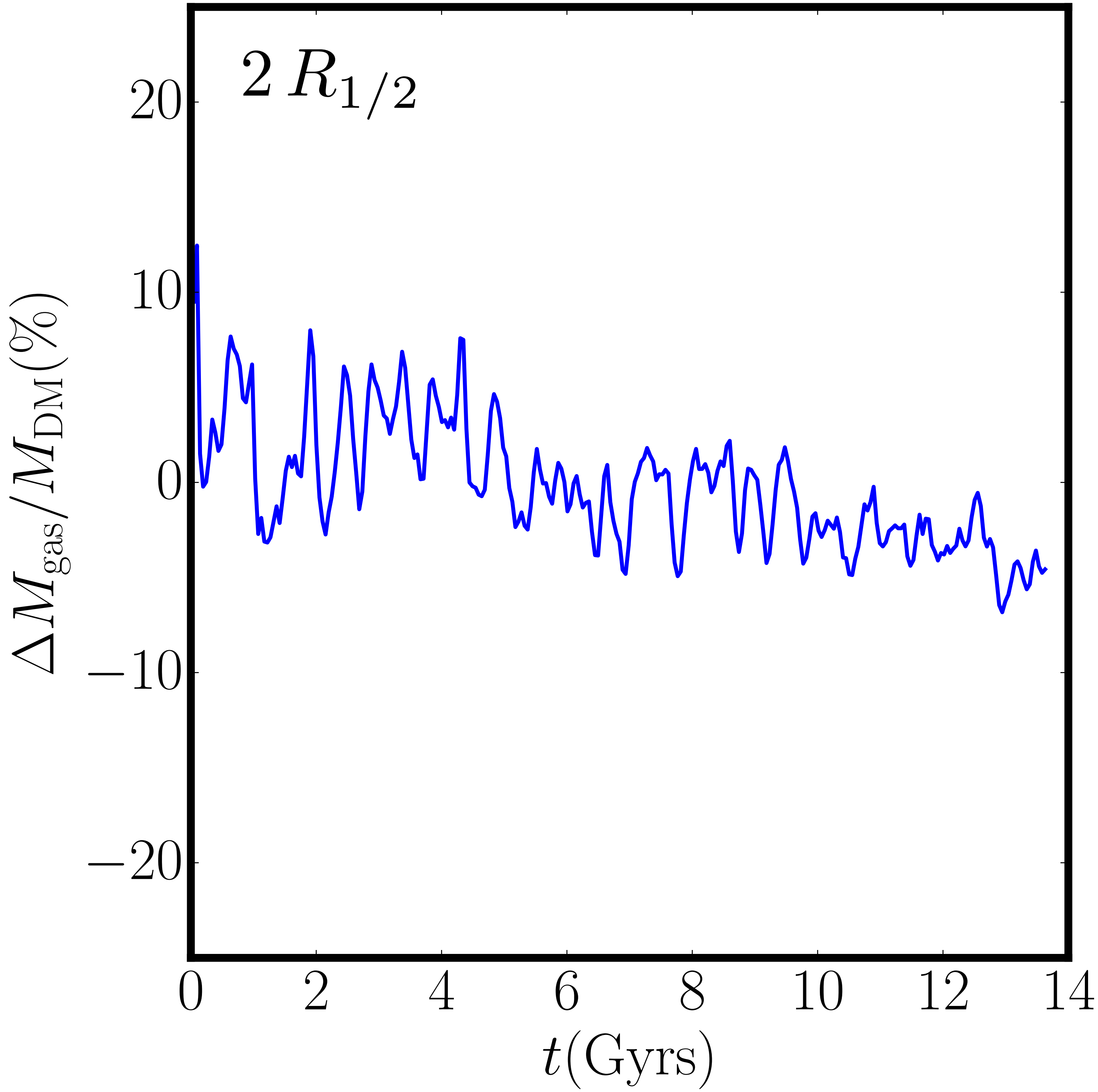
Read et al. 2016

Dark matter heating



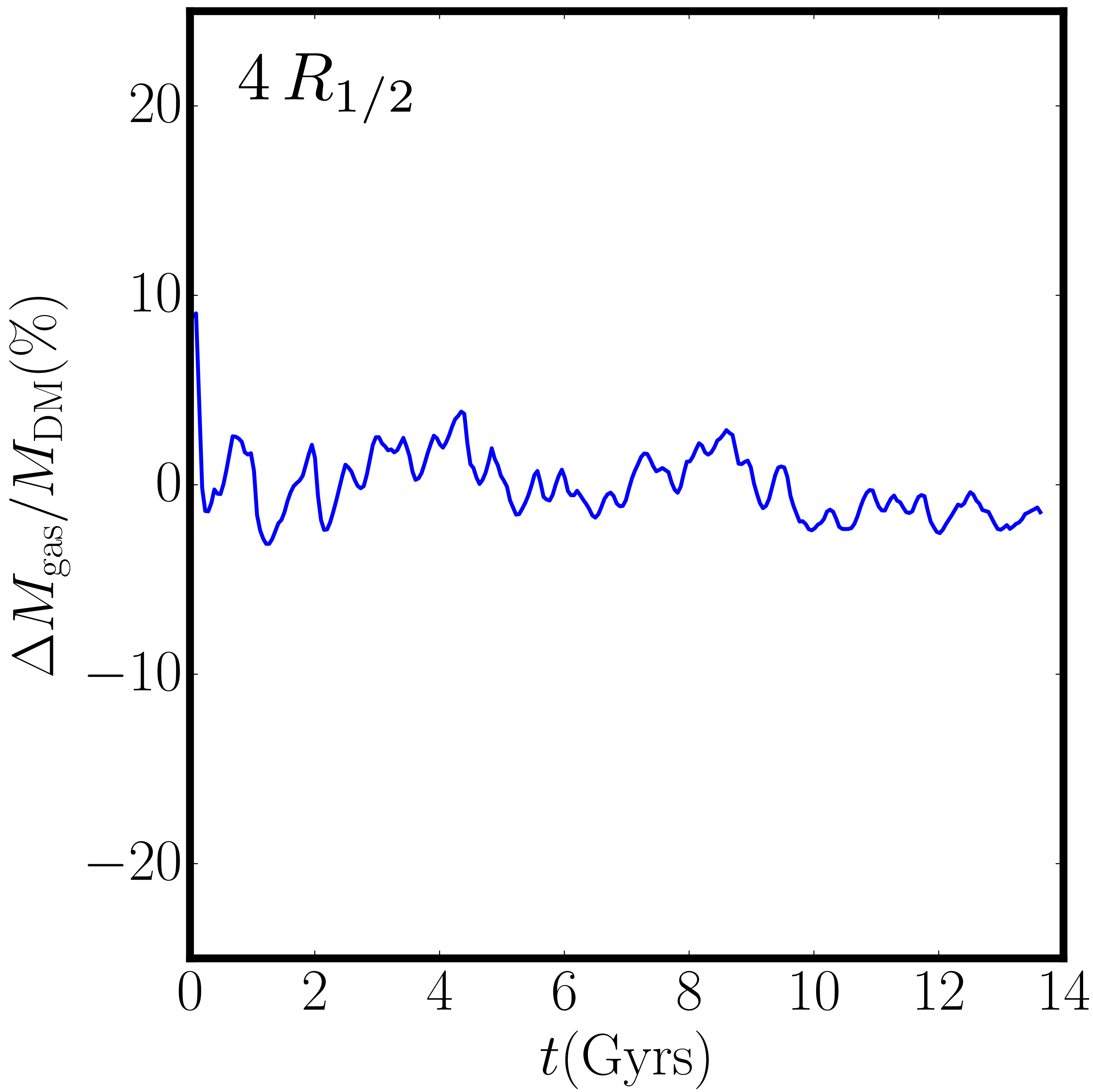
Read et al. 2016

Dark matter heating



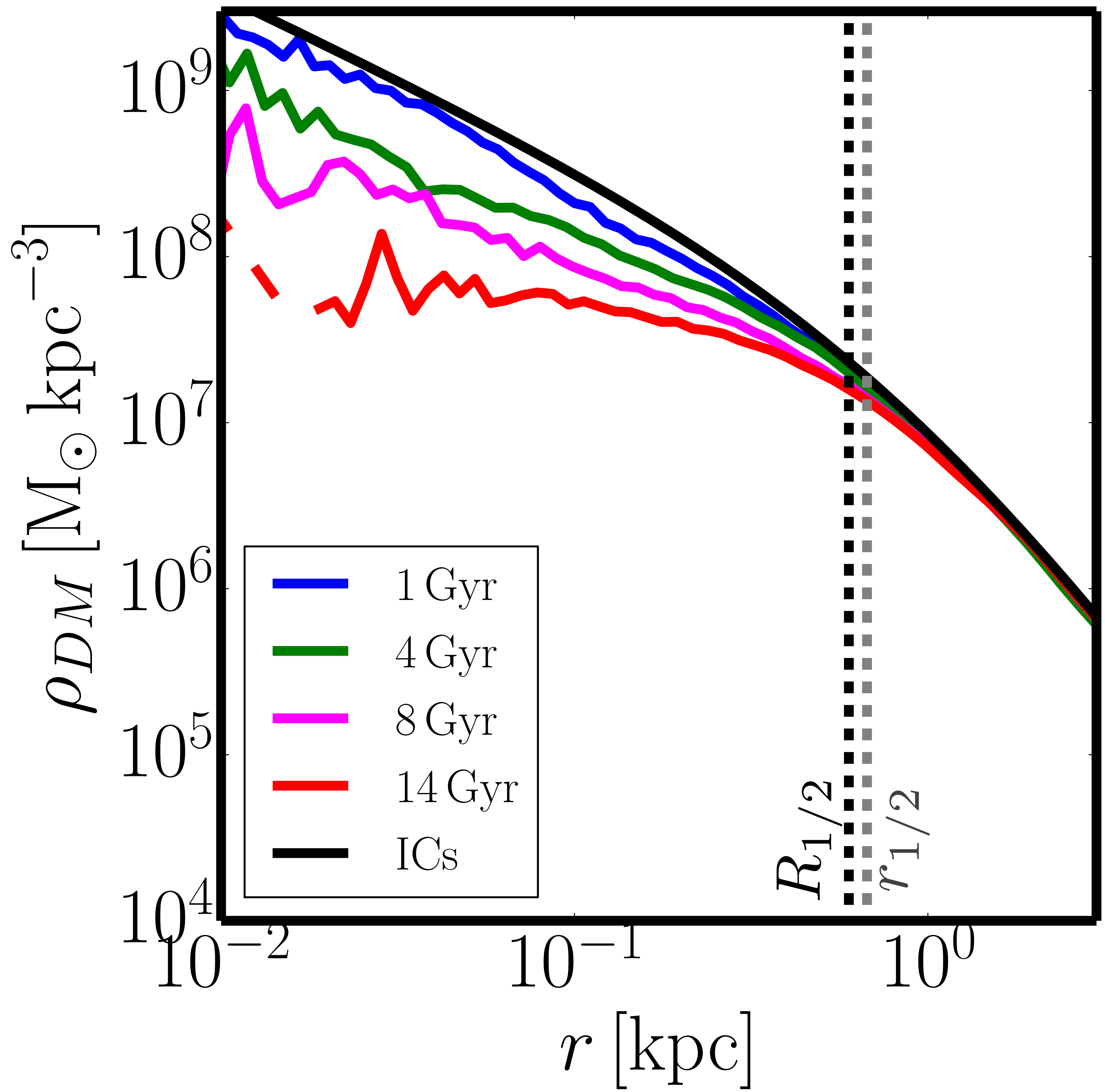
Read et al. 2016

Dark matter heating



Read et al. 2016

Dark matter heating



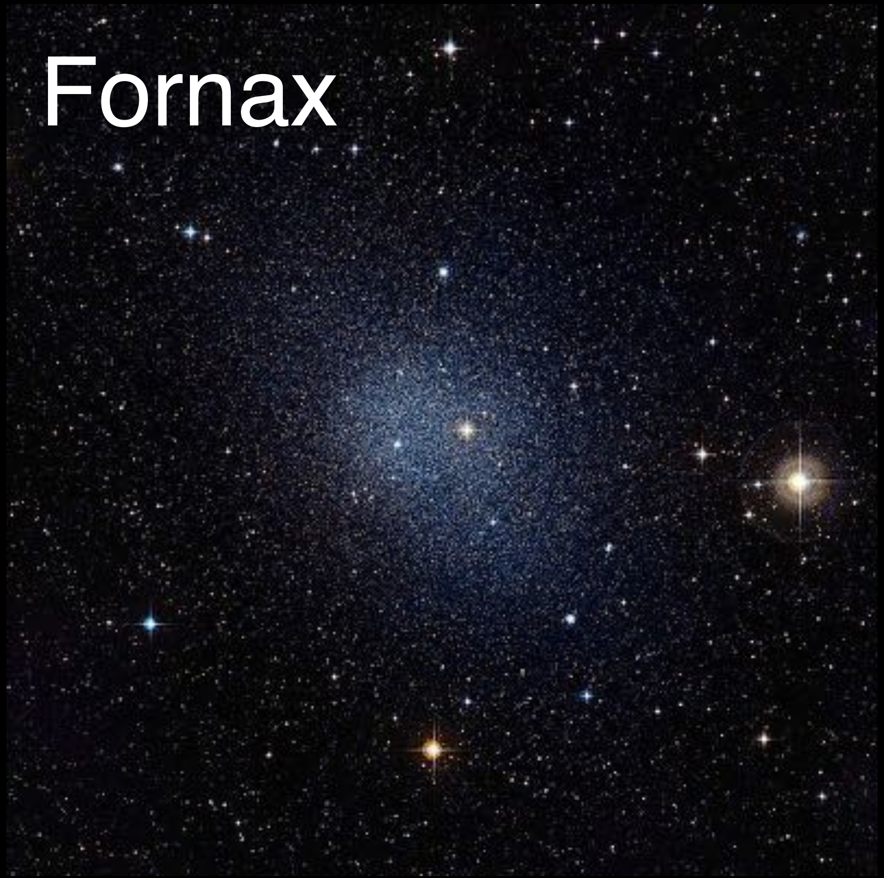
Read et al. 2016

“Smoking gun” evidence for DM heating

Less star formation ⇒ more cusp

UNIVERSITY OF SURREY

Leroy, Nature 2015



ESO/Digitized Sky Survey 2

Robert Lupton & SDSS

Decreasing star formation
⇒
More DM cusp!

Less star formation ⇒ more cusp

Leroy, Nature 2015

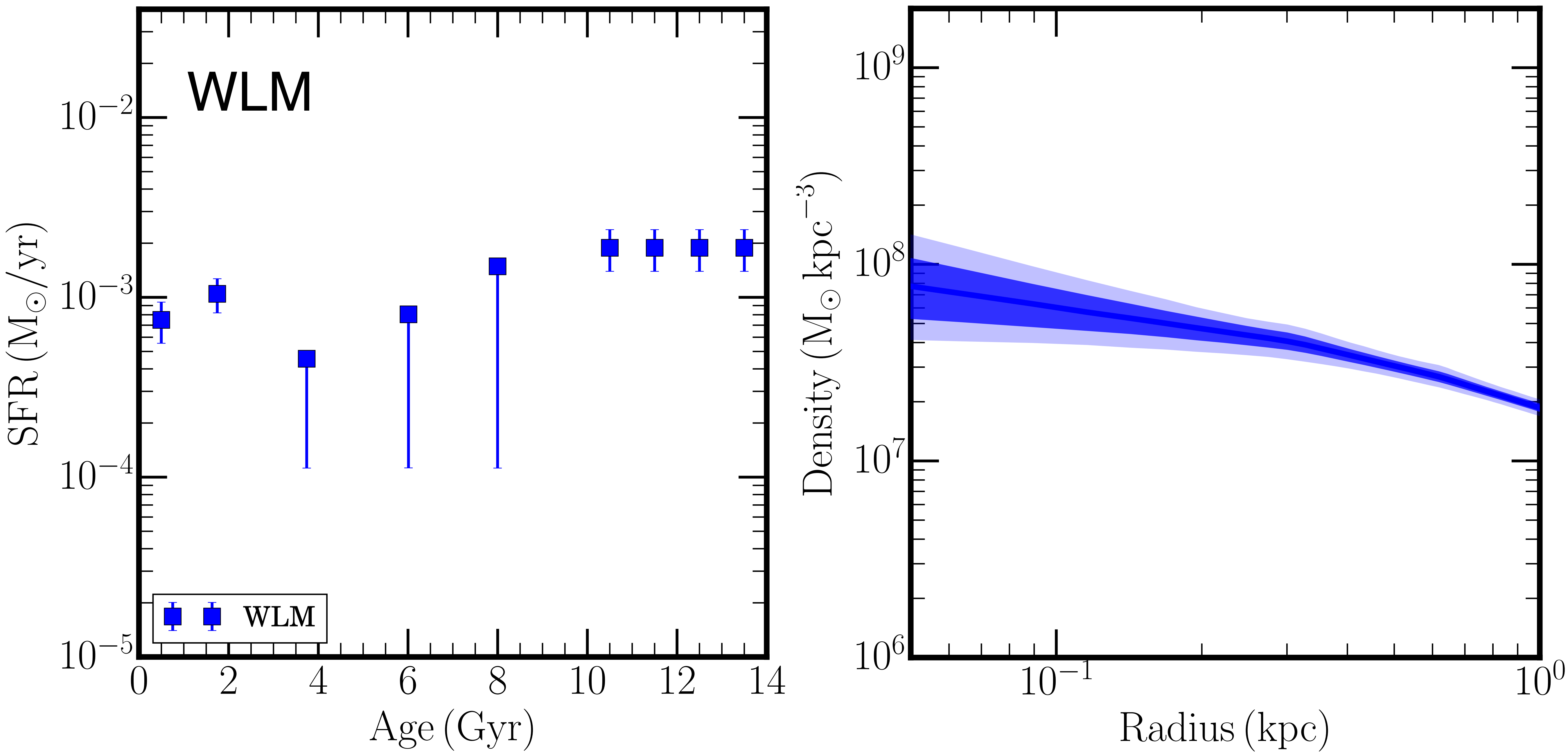
ESO/Digitized Sky Survey 2

Robert Lupton & SDSS

Rotation curves

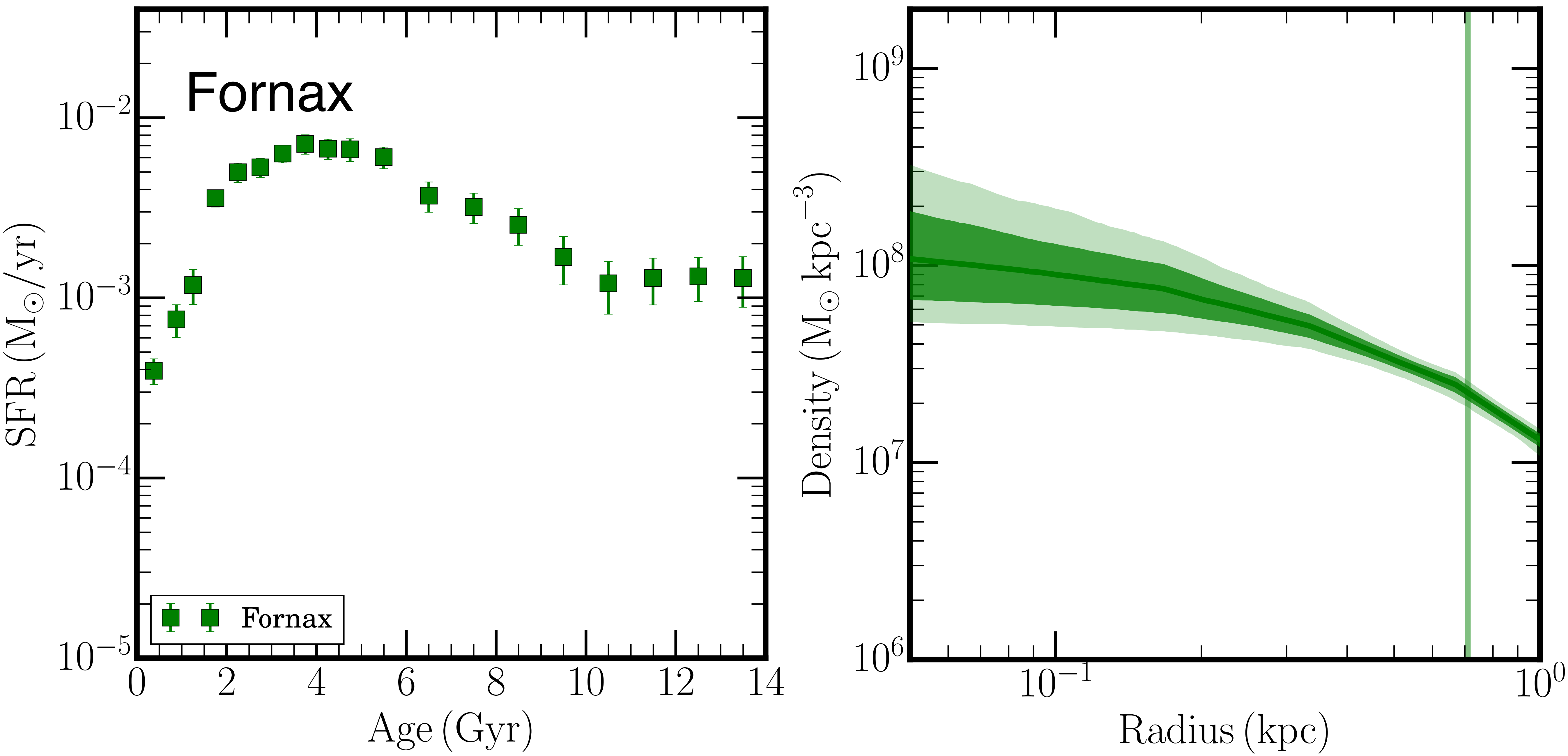
Stellar kinematics

Less star formation ⇒ more cusp



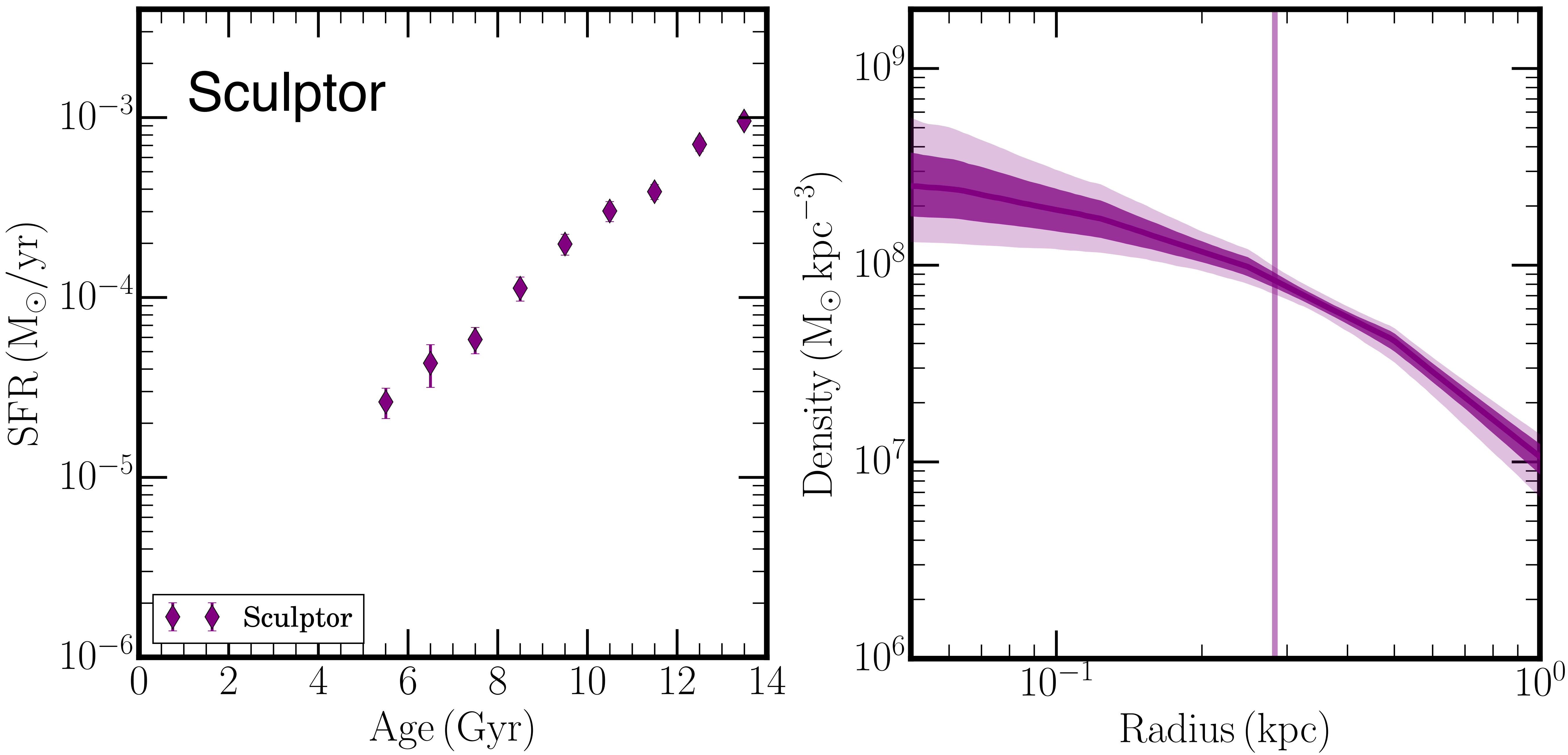
Read et al. 2018a,b,c: arXiv:1805.06934; arXiv:1807.07093; arXiv:1808.06634

Less star formation ⇒ more cusp



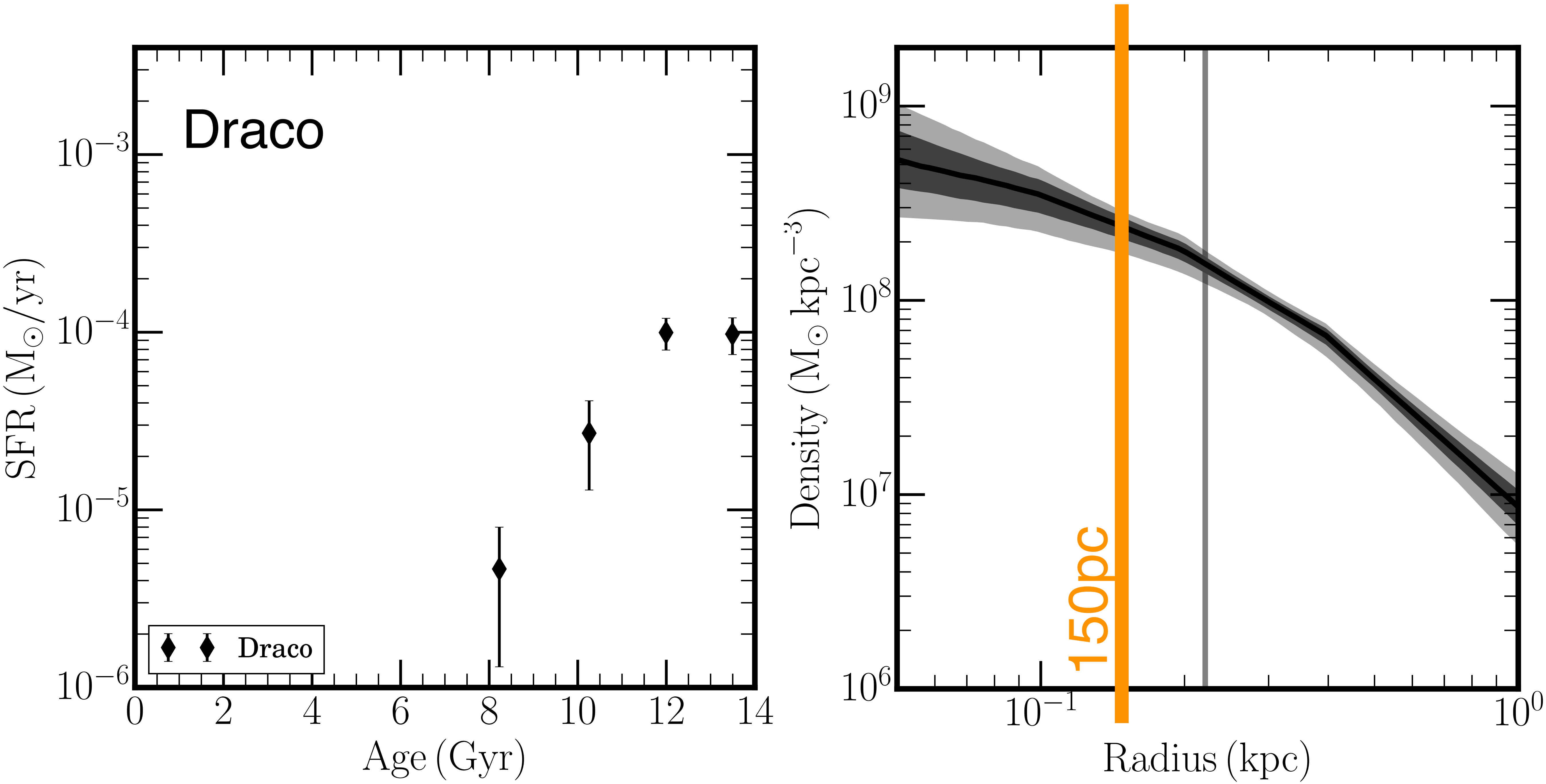
Read et al. 2018a,b,c: arXiv:1805.06934; arXiv:1807.07093; arXiv:1808.06634

Less star formation ⇒ more cusp

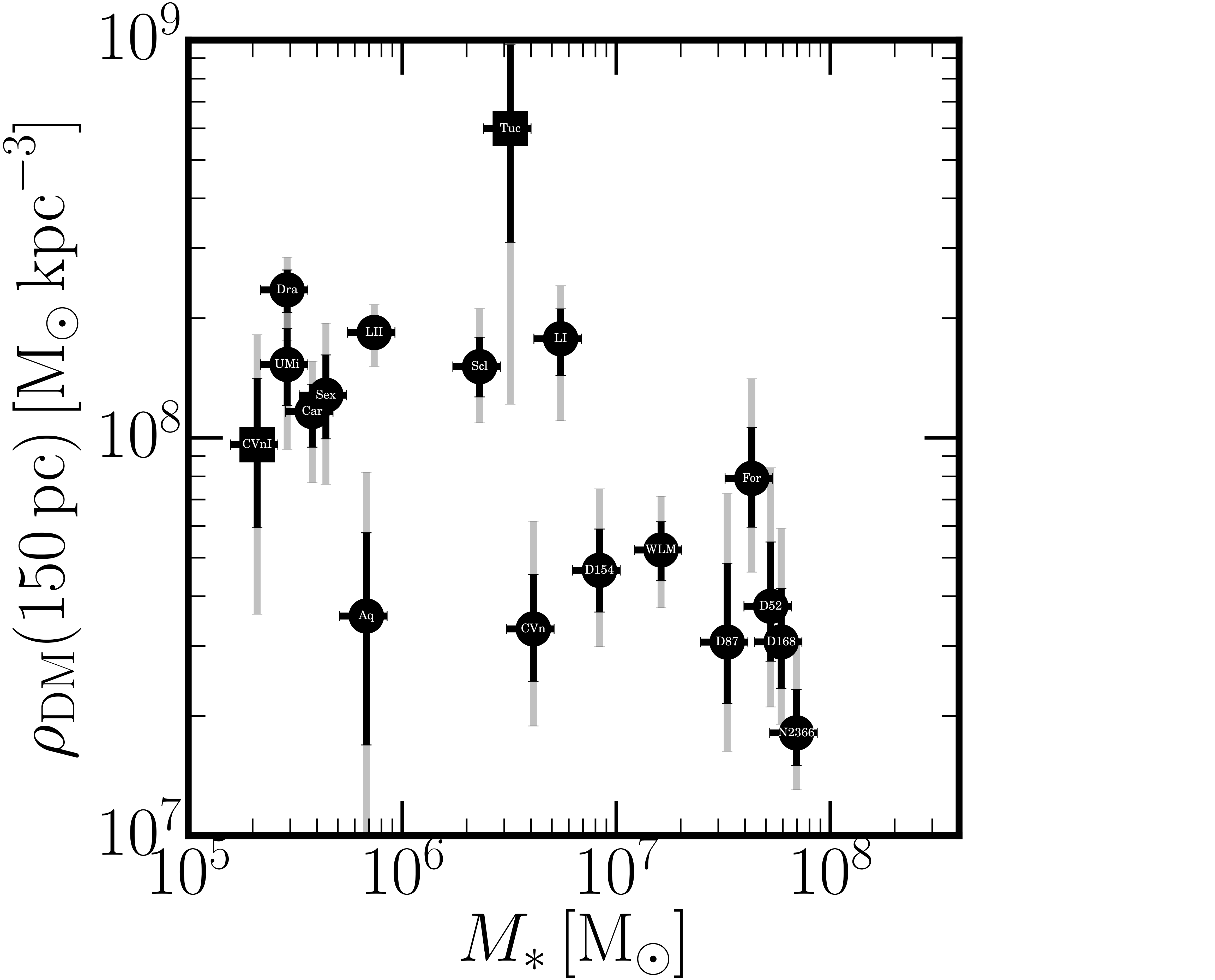


Read et al. 2018a,b,c: arXiv:1805.06934; arXiv:1807.07093; arXiv:1808.06634

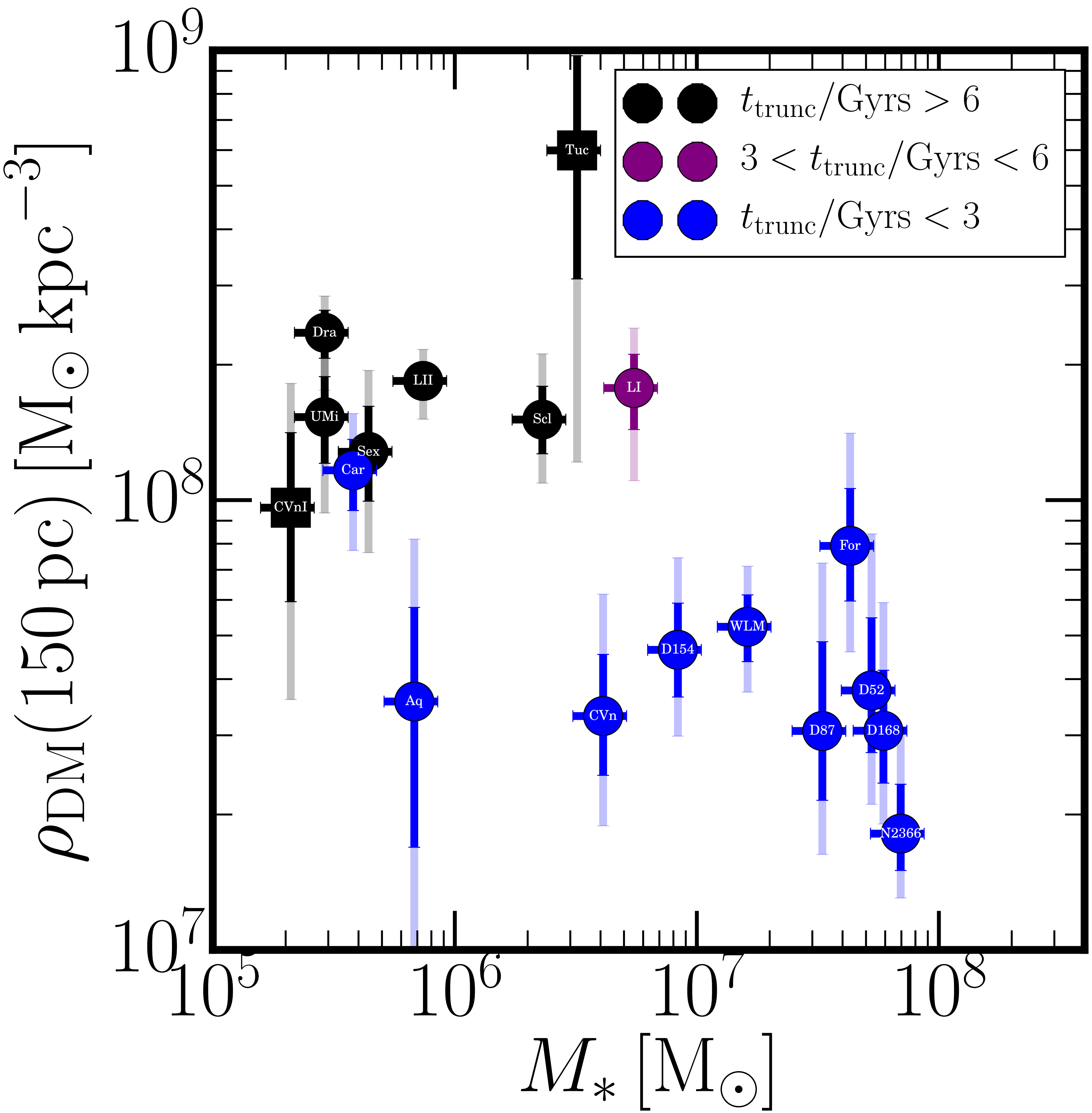
Less star formation ⇒ more cusp



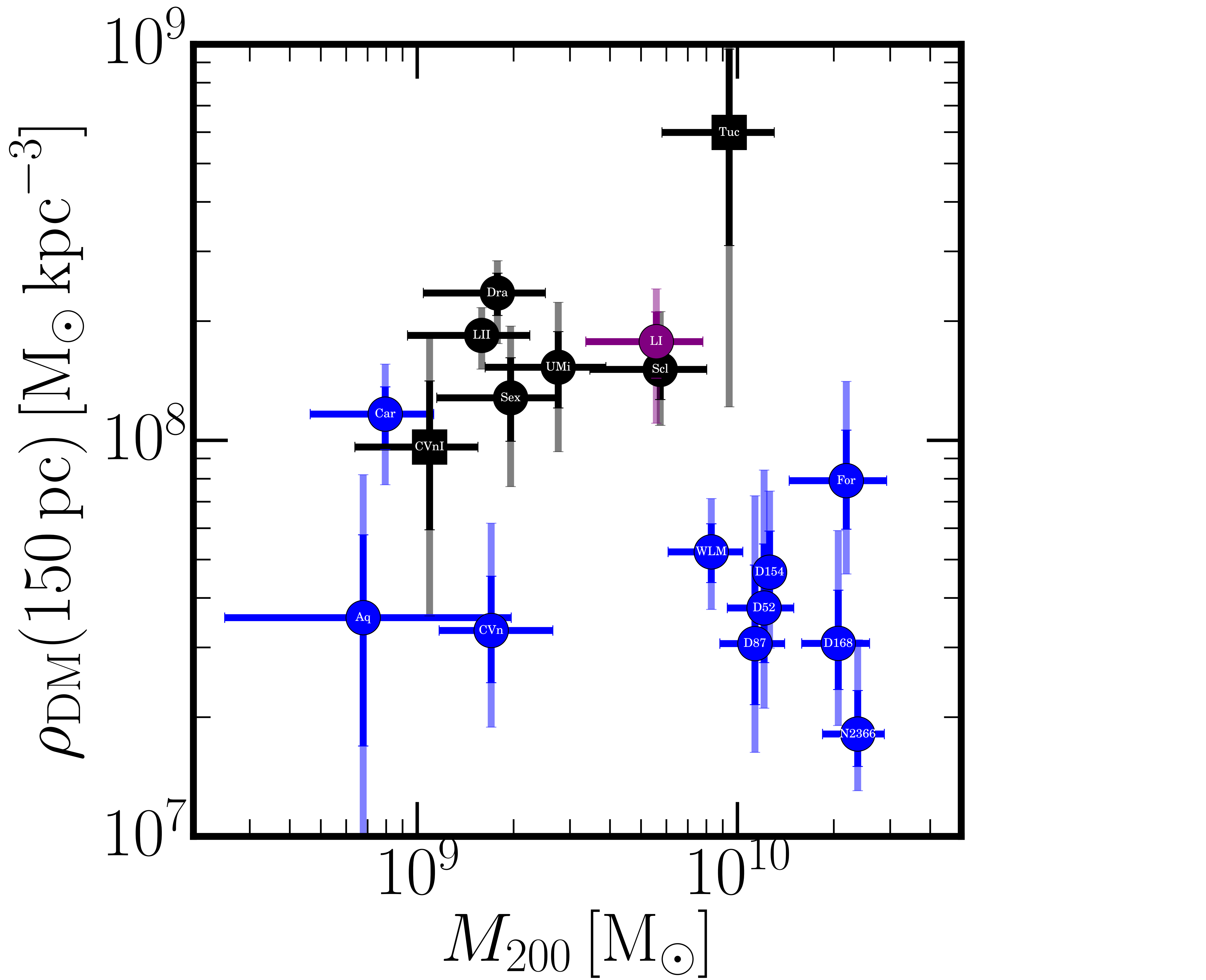
Read et al. 2018a,b,c: arXiv:1805.06934; arXiv:1807.07093; arXiv:1808.06634



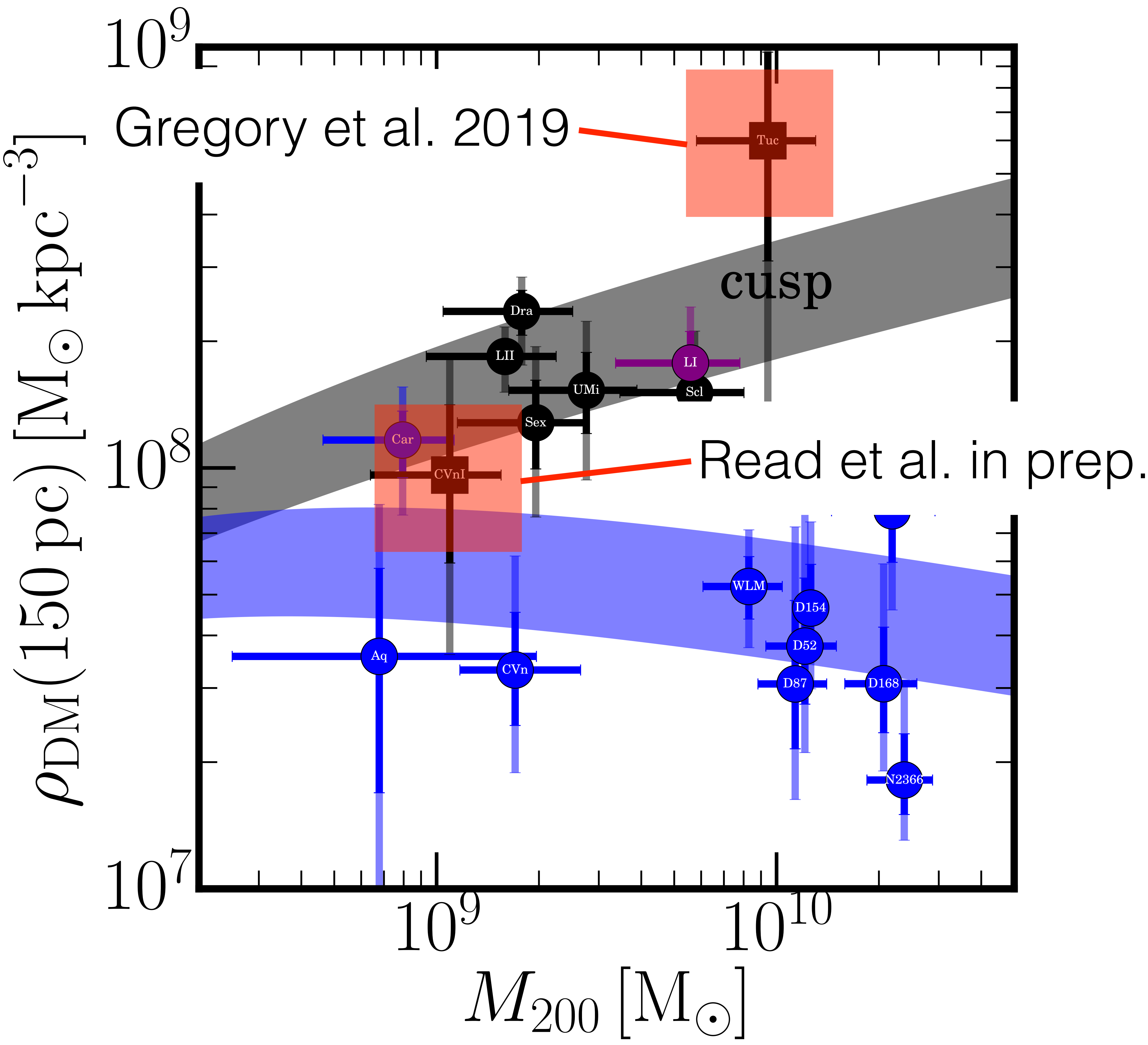
Read et al. 2018a,b,c: arXiv:1805.06934; arXiv:1807.07093; arXiv:1808.06634; Gregory et al. 2019



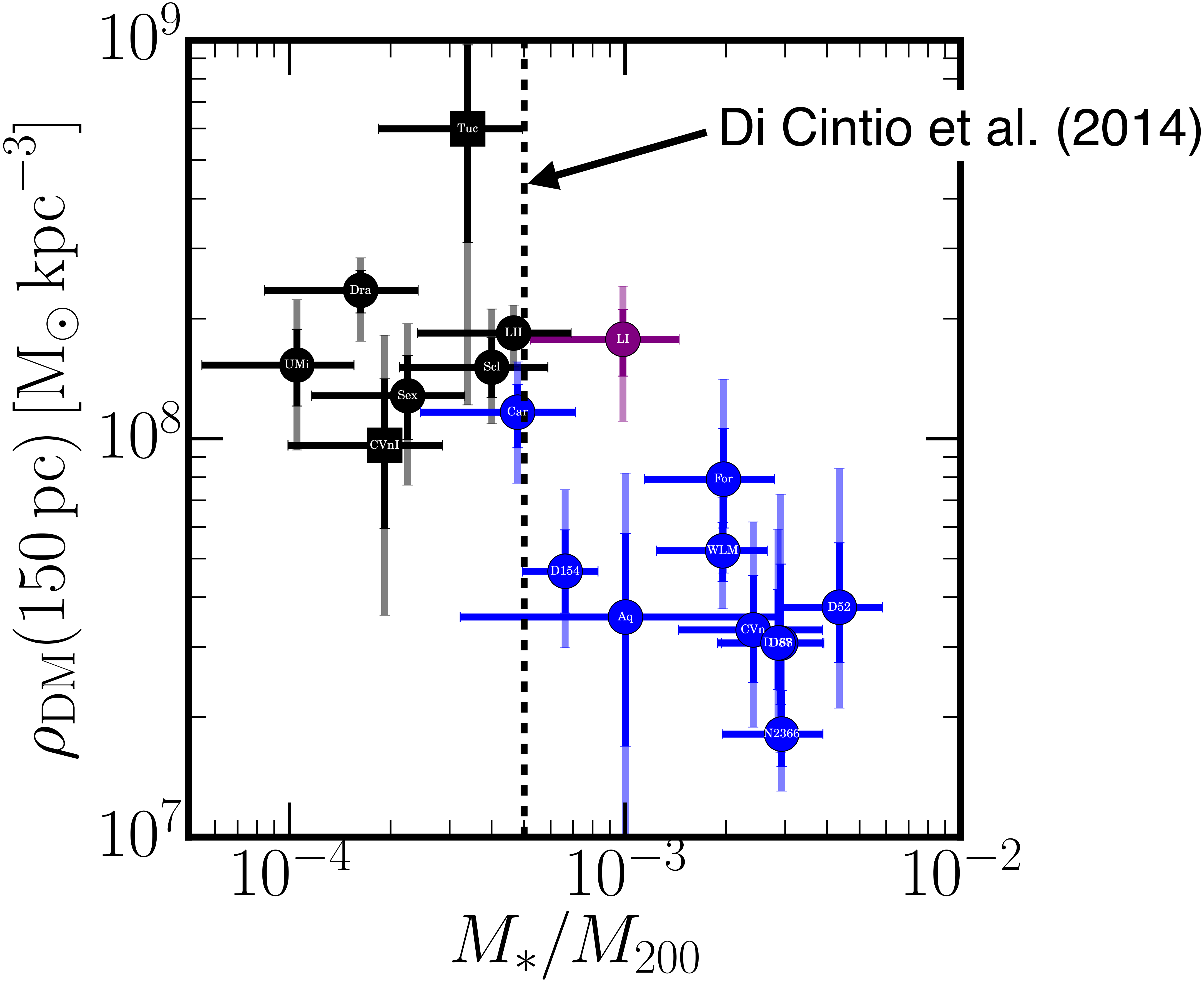
Read et al. 2018a,b,c: arXiv:1805.06934; arXiv:1807.07093; arXiv:1808.06634; Gregory et al. 2019



Read et al. 2018a,b,c: arXiv:1805.06934; arXiv:1807.07093; arXiv:1808.06634; Gregory et al. 2019

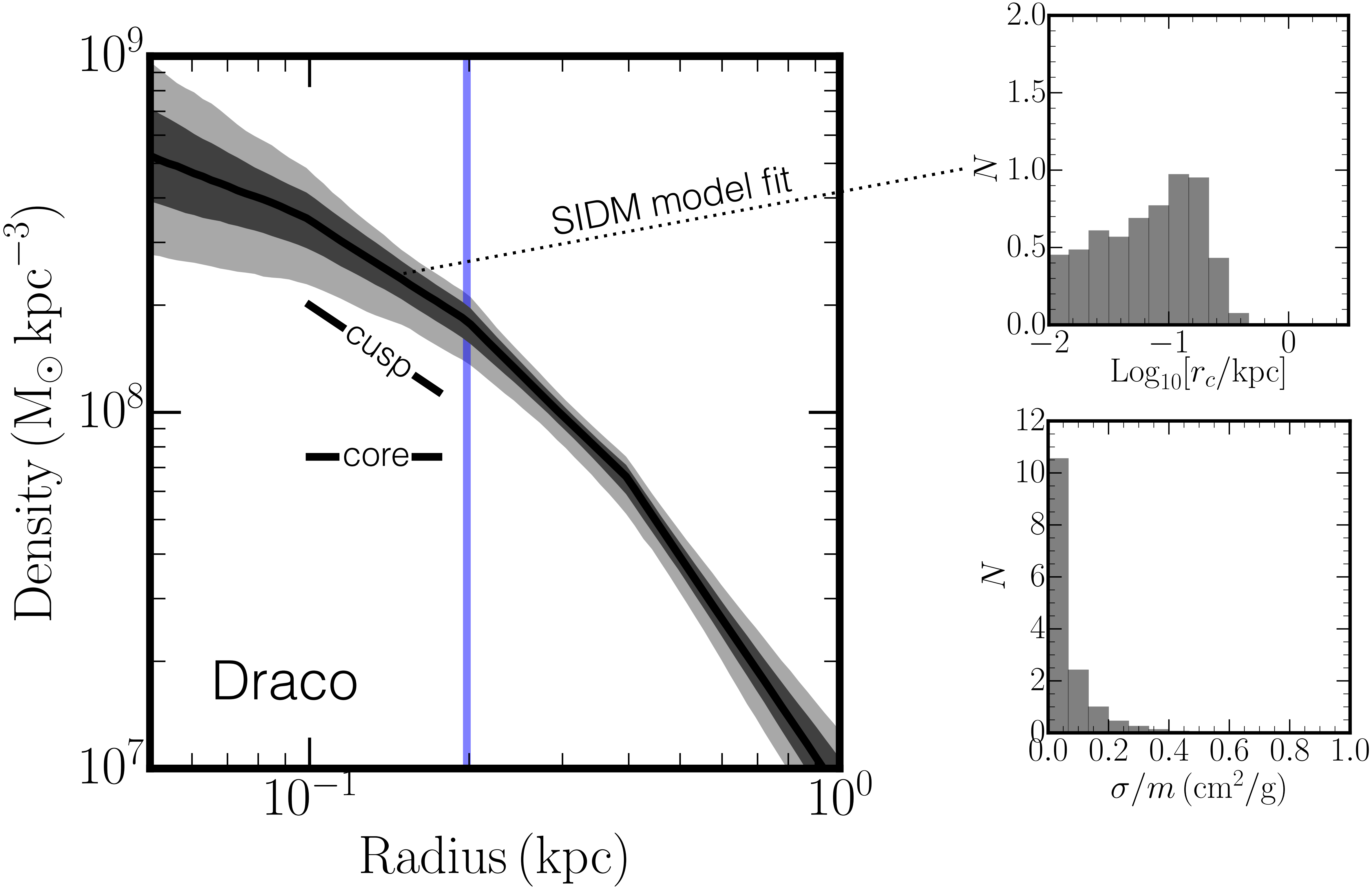


Read et al. 2018a,b,c: arXiv:1805.06934; arXiv:1807.07093; arXiv:1808.06634; Gregory et al. 2019



Read et al. 2018a,b,c: arXiv:1805.06934; arXiv:1807.07093; arXiv:1808.06634; Gregory et al. 2019

Self interacting dark matter

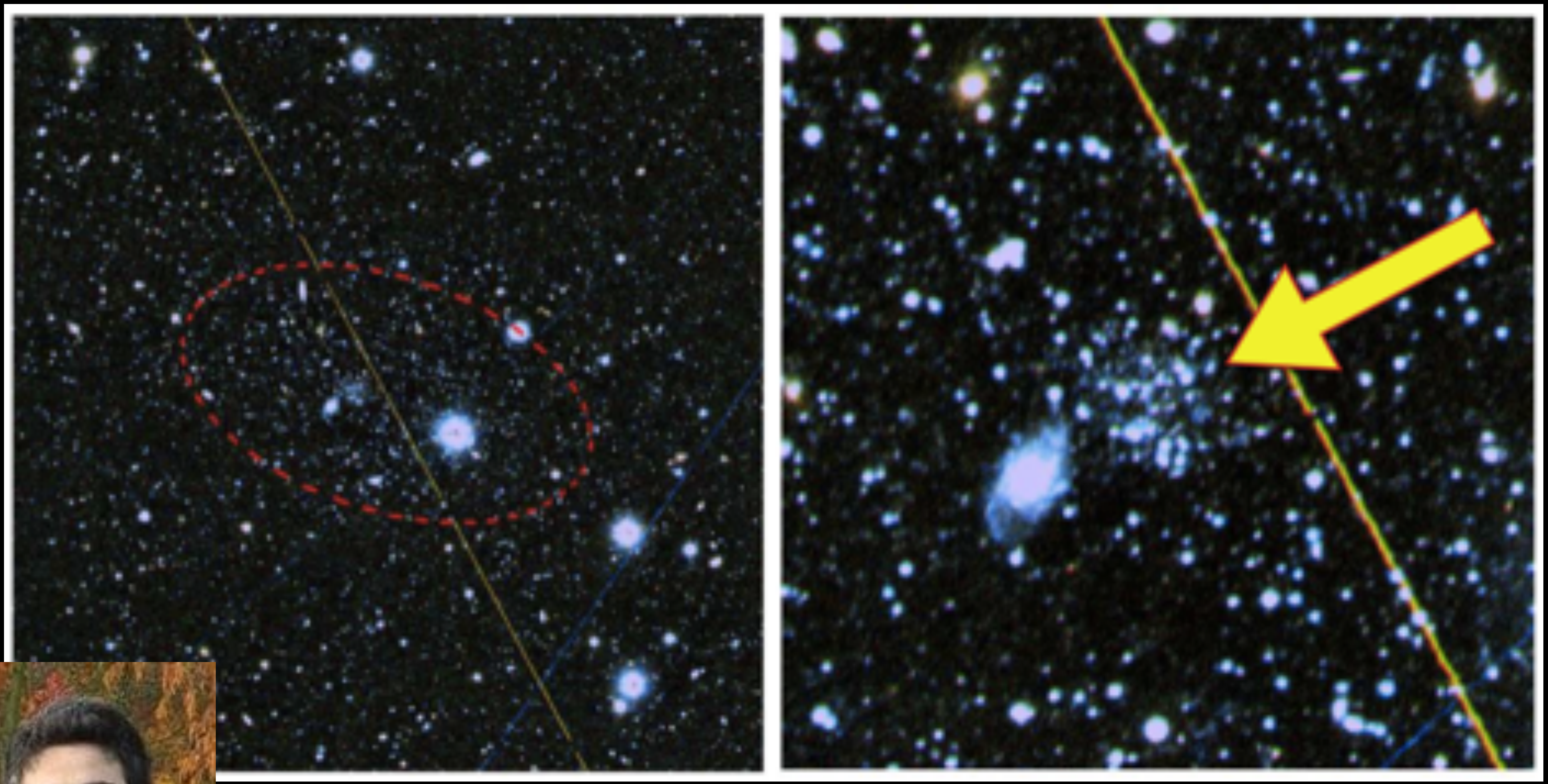


$$\sigma/m \; < \; 0.57\,\mathrm{cm}^2\,\mathrm{g}^{-1} \;\; \text{at} \;\; 99\% \;\; \text{confidence.}$$

Read et al. 2018 (arXiv:1805.06934)

Ultra-faints

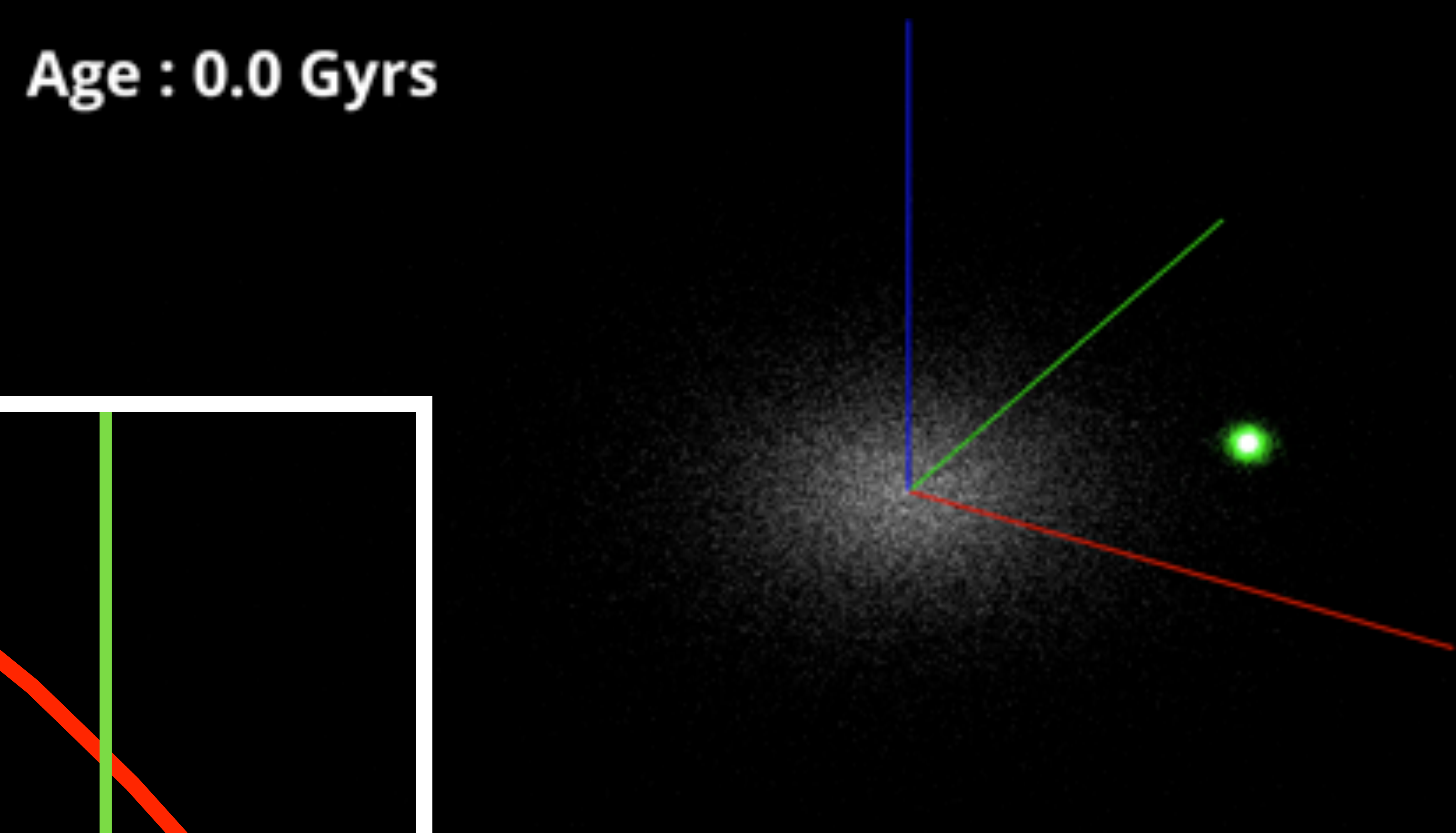
A dark matter core in an ultra-faint dwarf

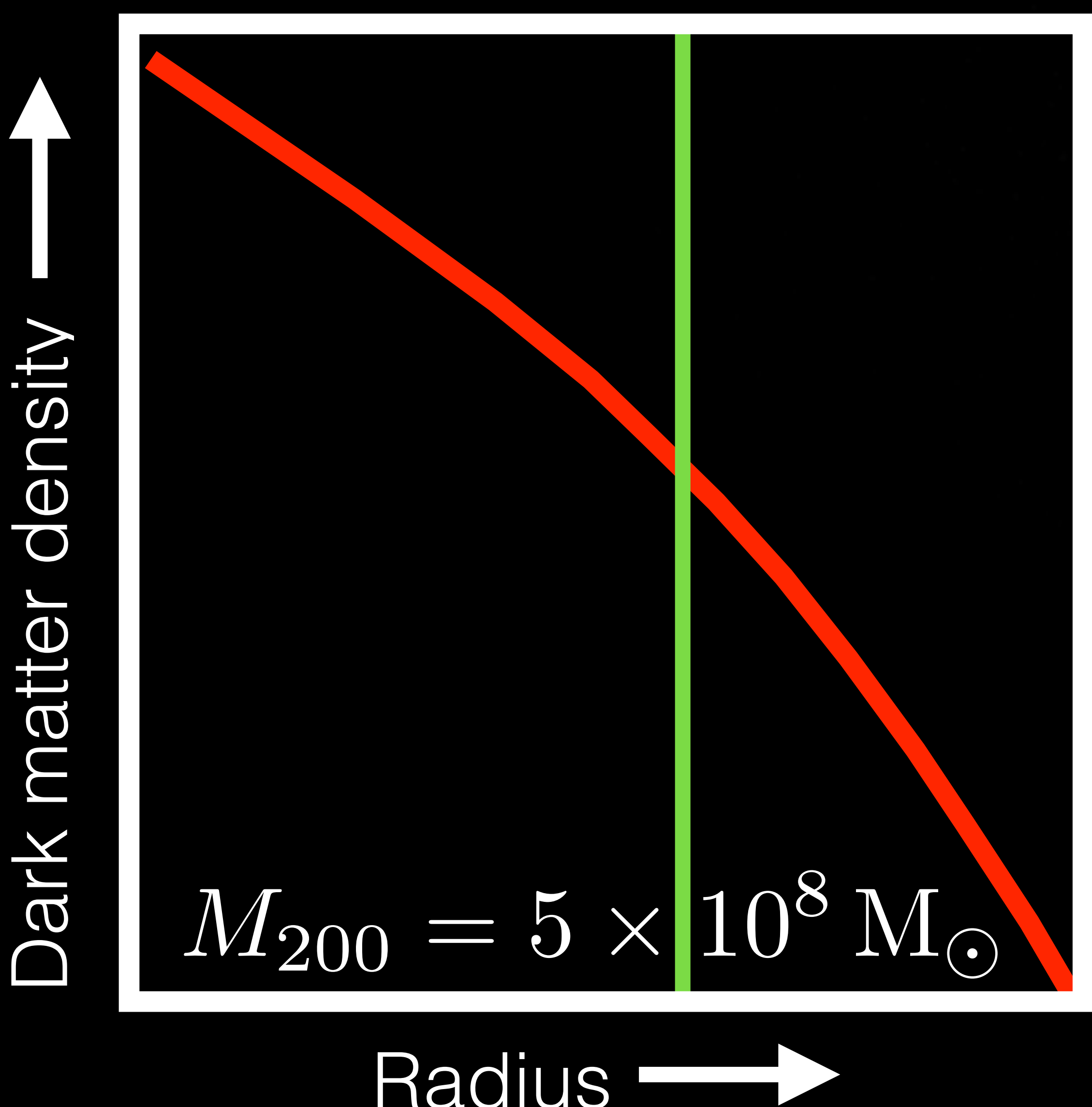


Contenta et al. 2017; Koposov et al. 2015; Crnojevic et al. 2016; Amorisco 2017

A dark matter core in an ultra-faint dwarf

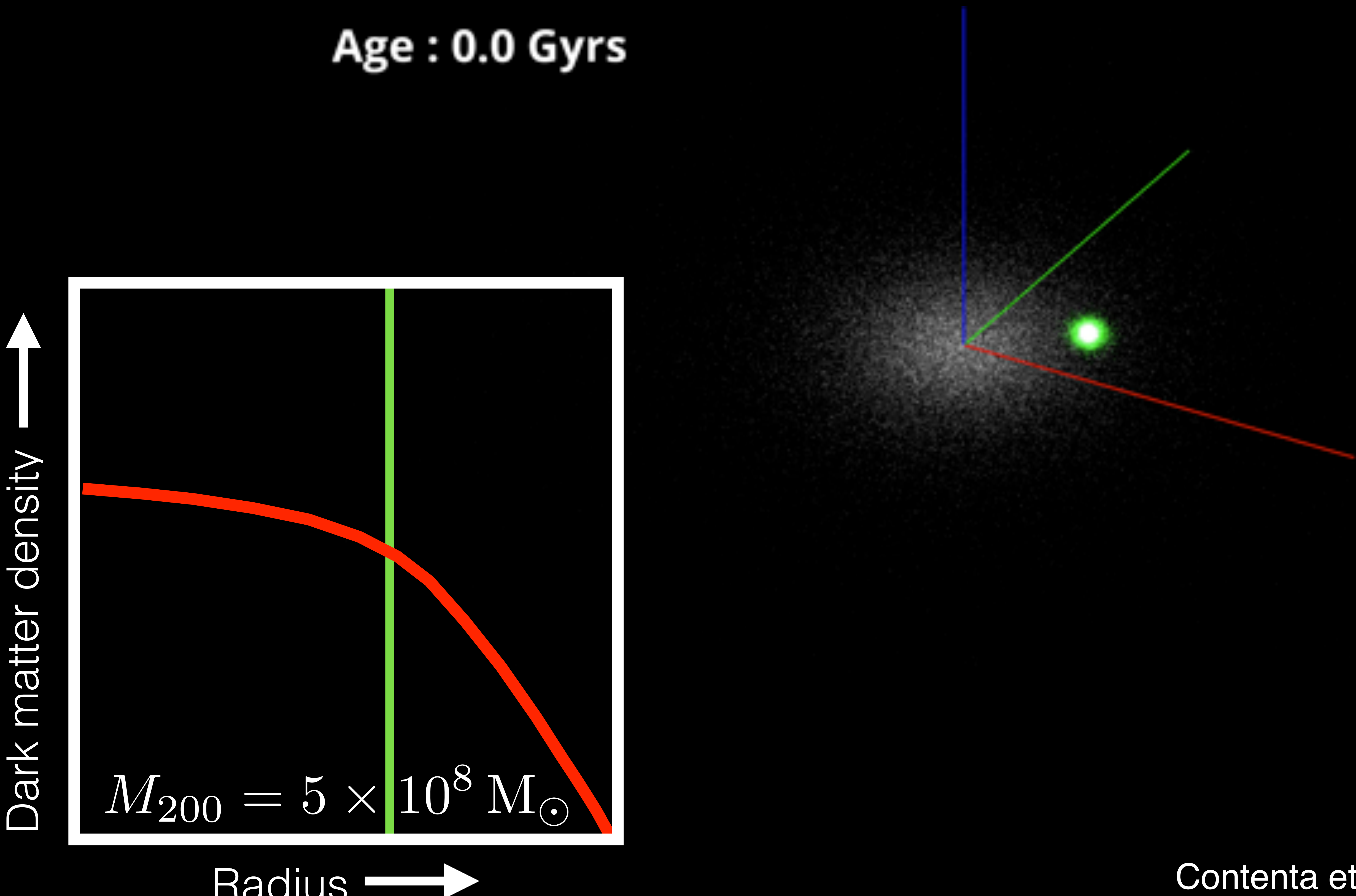
UNIVERSITY OF SURREY





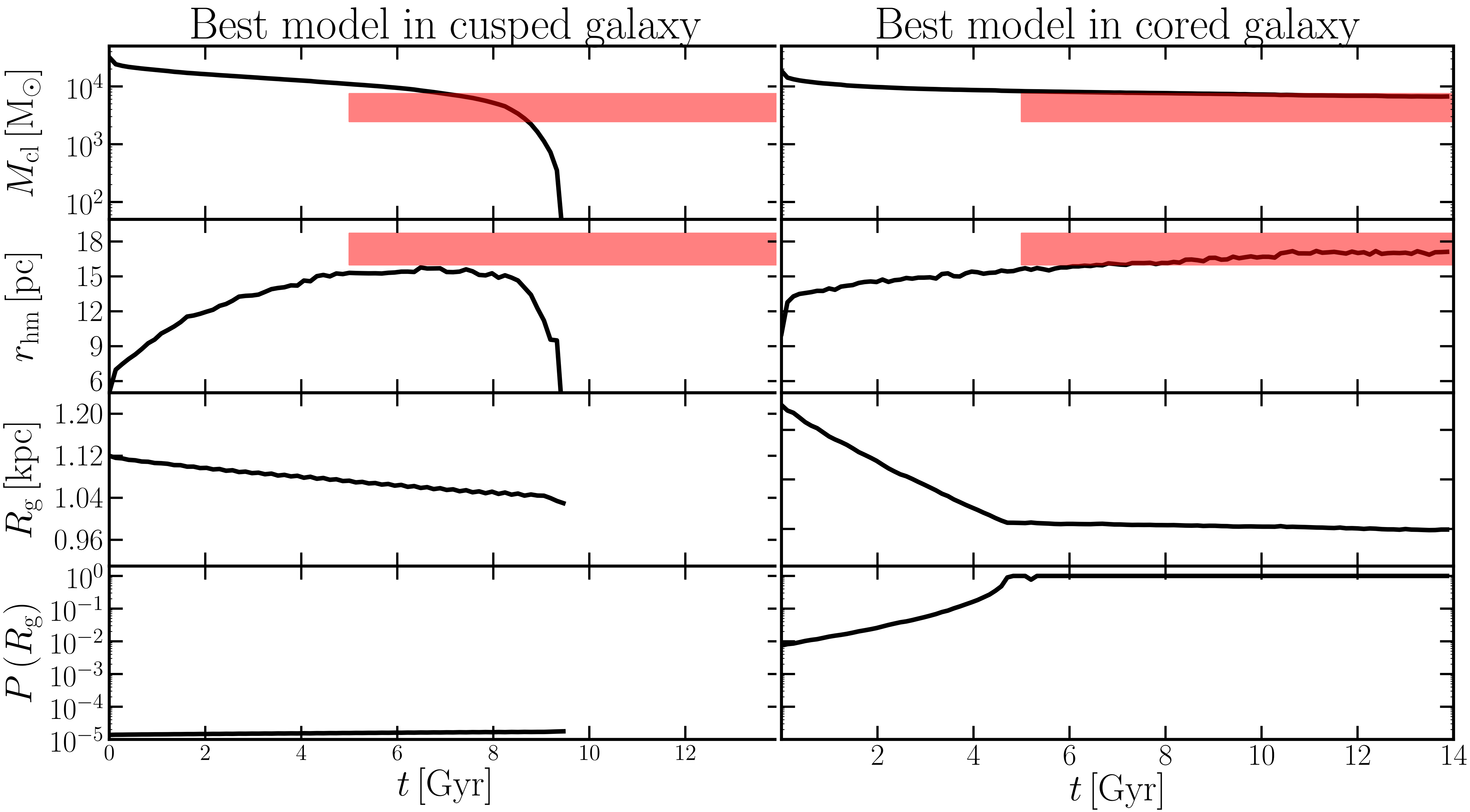
Contenta et al. 2017

A dark matter core in an ultra-faint dwarf



Contenta et al. 2017

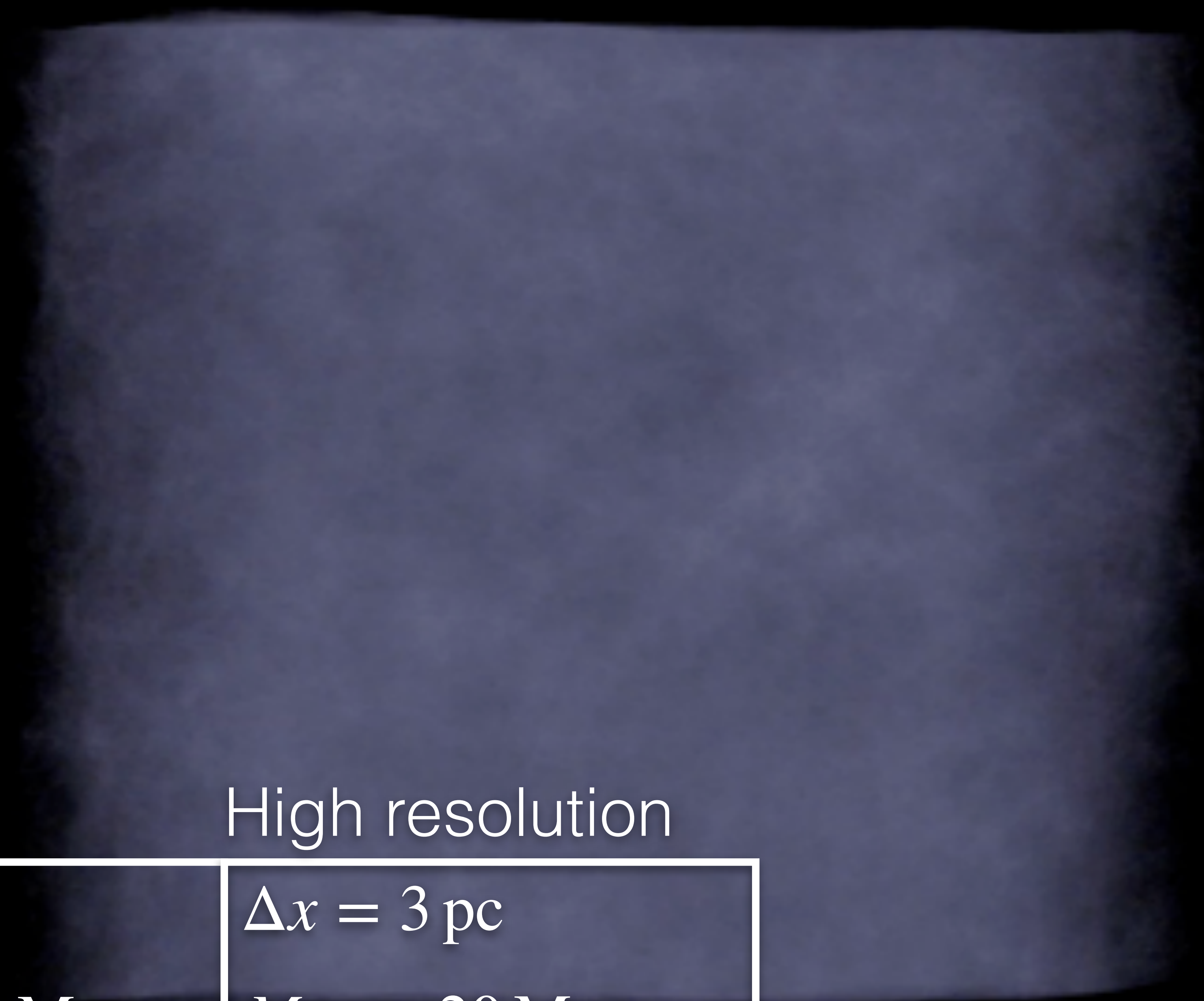
A dark matter core in an ultra-faint dwarf



Contenta et al. 2017

E.D.G.E.

UNIVERSITY OF SURREY



Fiducial	High resolution
$\Delta x = 3\,\mathrm{pc}$	$\Delta x = 3\,\mathrm{pc}$
$M_{\mathrm{bar}} = 161\,\mathrm{M}_{\odot}$	$M_{\mathrm{bar}} = 20\,\mathrm{M}_{\odot}$
$M_{\mathrm{dm}} = 945\,\mathrm{M}_{\odot}$	$M_{\mathrm{dm}} = 118\,\mathrm{M}_{\odot}$

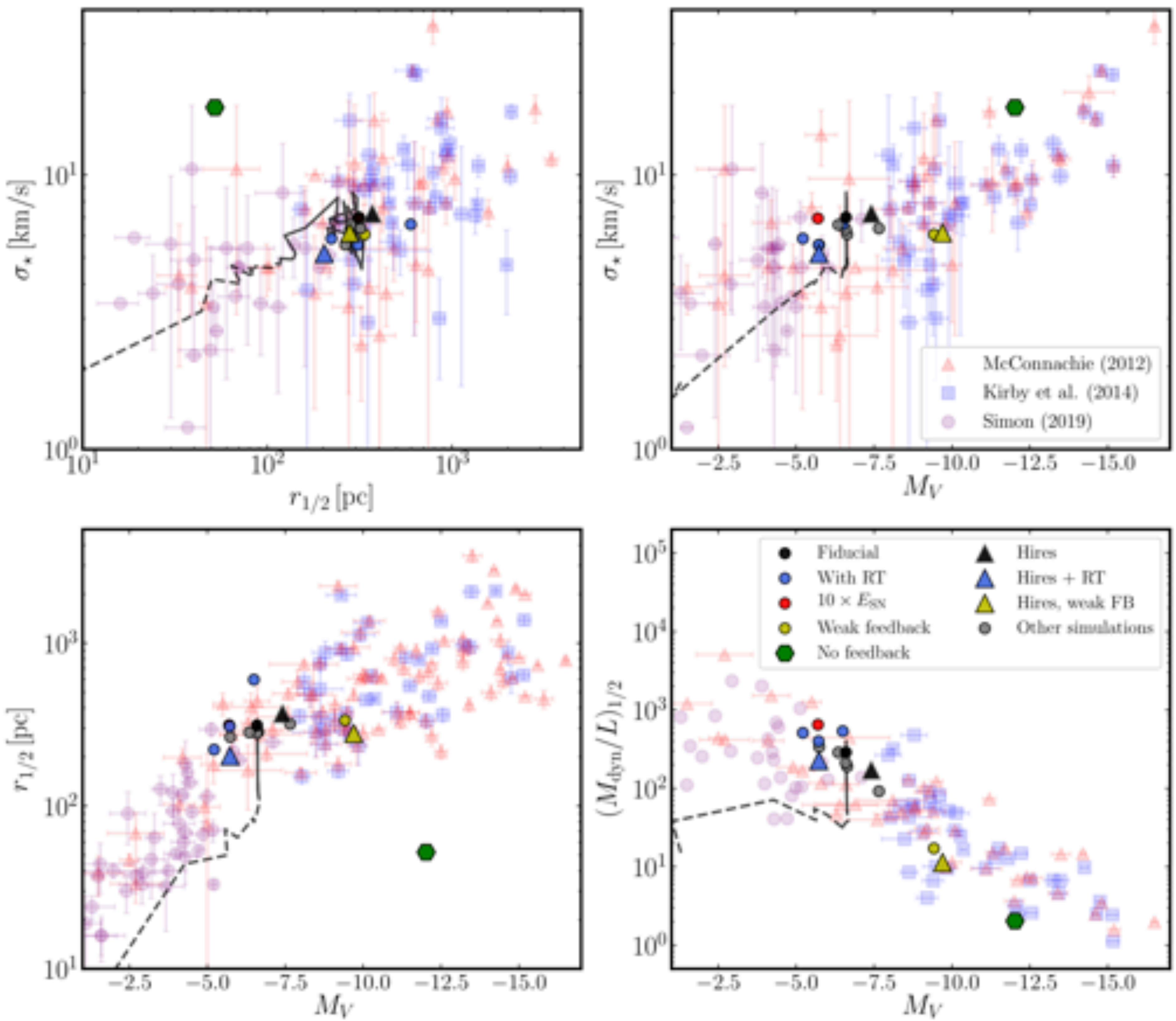
Agertz et al. 2019 | arXiv:1904.02723

$z = 18.27$

Fiducial

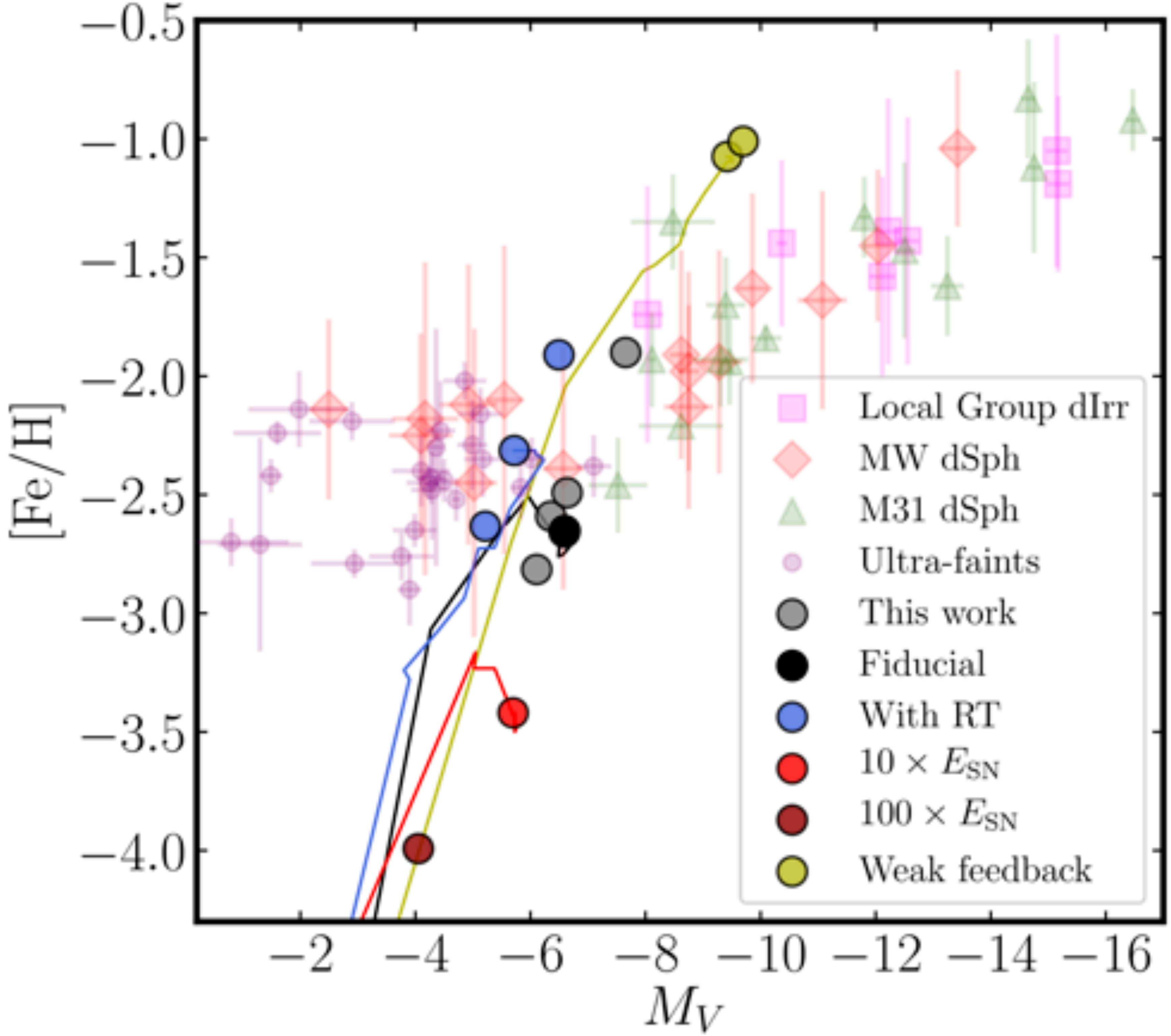
Agertz et al. 2019 | arXiv:1904.02723

E.D.G.E.



Agertz et al. 2019 | arXiv:1904.02723

E.D.G.E.



Agertz et al. 2019 | arXiv:1904.02723

Conclusions

Conclusions

- We have found "smoking gun" evidence for dark matter heating in dwarf galaxies.
- Dwarfs with more star formation have lower central dark matter densities.
- At least some ultra-faint dwarfs appear to have dark matter cores.
- Our new "EDGE" simulation campaign will shed light on the formation and evolution of the smallest galaxies.

Justin I. Read