Project Purple Rain ♀:
When Doves Cry, Satellites Quench

Mike Cooper
UC Irvine

Tim Carleton (UCI), **Sean Fillingham** (UCI), M. Katy Rodriguez Wimberly (UCI)
John Phillips (Minnesota), Coral Wheeler (Caltech),
Mike Boylan-Kolchin (UT Austin), James Bullock (UCI)

along with Shea Garrison-Kimmel, Manoj Kaplinghat, and Jorge Peñarrubia

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS **454**, 2039–2049 (2015) doi:10.1093/mnras/stv2058

Taking care of business in a flash ⚡: constraining the time-scale for low-mass satellite quenching with ELVIS

Sean P. Fillingham,[1★] Michael C. Cooper,[1★] Coral Wheeler,[1] Shea Garrison-Kimmel,[1] Michael Boylan-Kolchin[2,3] and James S. Bullock[1]

[1] *Center for Cosmology, Department of Physics and Astronomy, 4129 Reines Hall, University of*
[2] *Department of Astronomy and Joint Space-Science Institute, University of Maryland, College P*
[3] *Department of Astronomy, The University of Texas at Austin, 2515 Speedway, Stop C1400, Aust*

running title — *TCB⚡: the mass dependence of satellite quenching*

uench

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS **463**, 1916–1928 (2016) doi:10.1093/mnras/stw2131
Advance Access publication 2016 August 24

Under pressure: quenching star formation in low-mass satellite galaxies via stripping

Sean P. Fillingham,[1★] Michael C. Cooper,[1★] Andrew B. Pace,[1] Michael Boylan-Kolchin,[2] James S. Bullock,[1] Shea Garrison-Kimmel[3†] and Coral Wheeler[1]

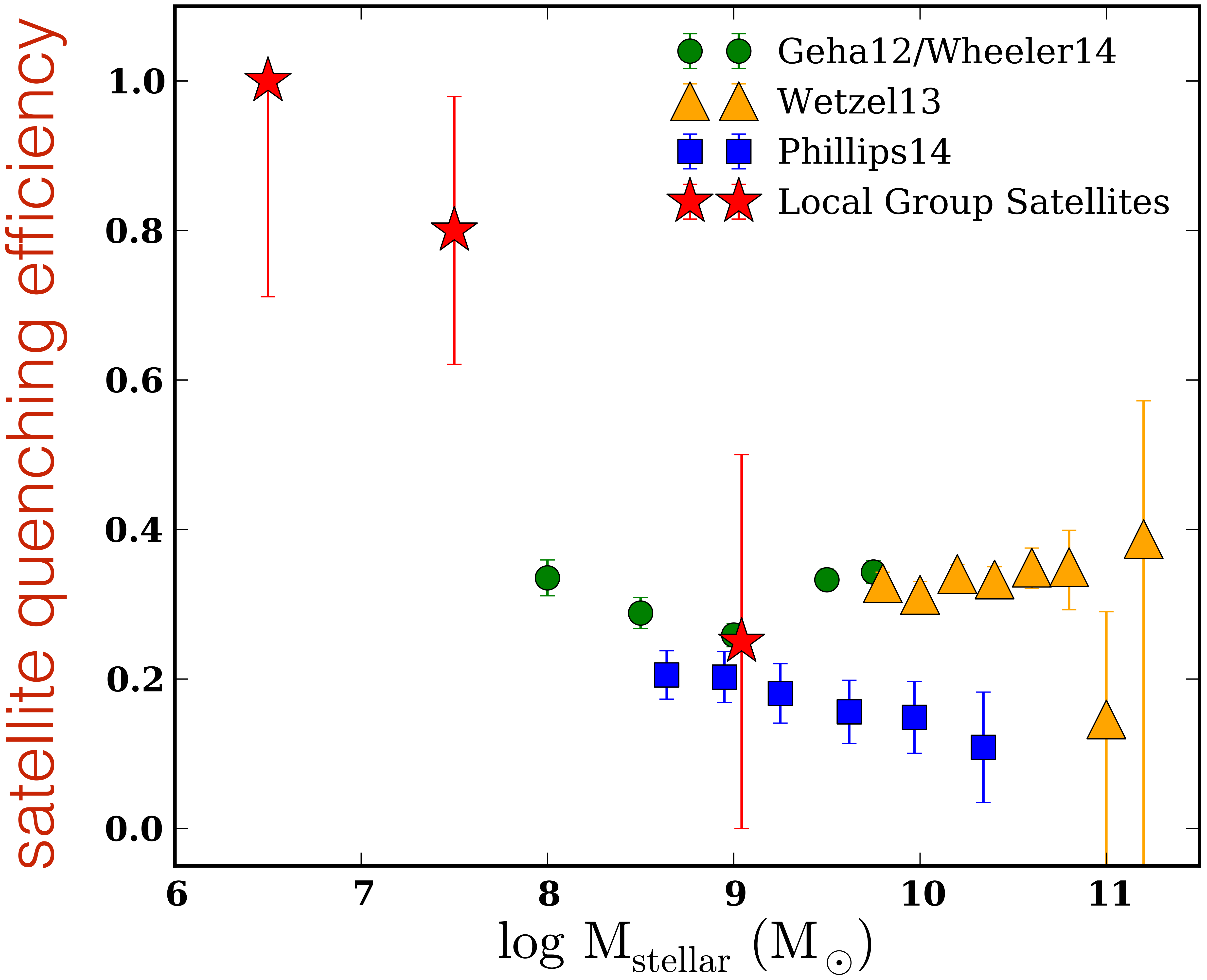
[1] *Center for Cosmology, Department of Physics and Astronomy, 4129 Reines Hall, University of Cali*
[2] *Department of Astronomy, The University of Texas at Austin, 2515 Speedway, Stop C1400, Austin, T*
[3] *TAPIR, Mailcode 350-17, California Institute of Technology, Pasadena, CA 91125, USA*

mberly (UCI)

eñarrubia

running title — *Ch-Ch-changing satellites via stripping*

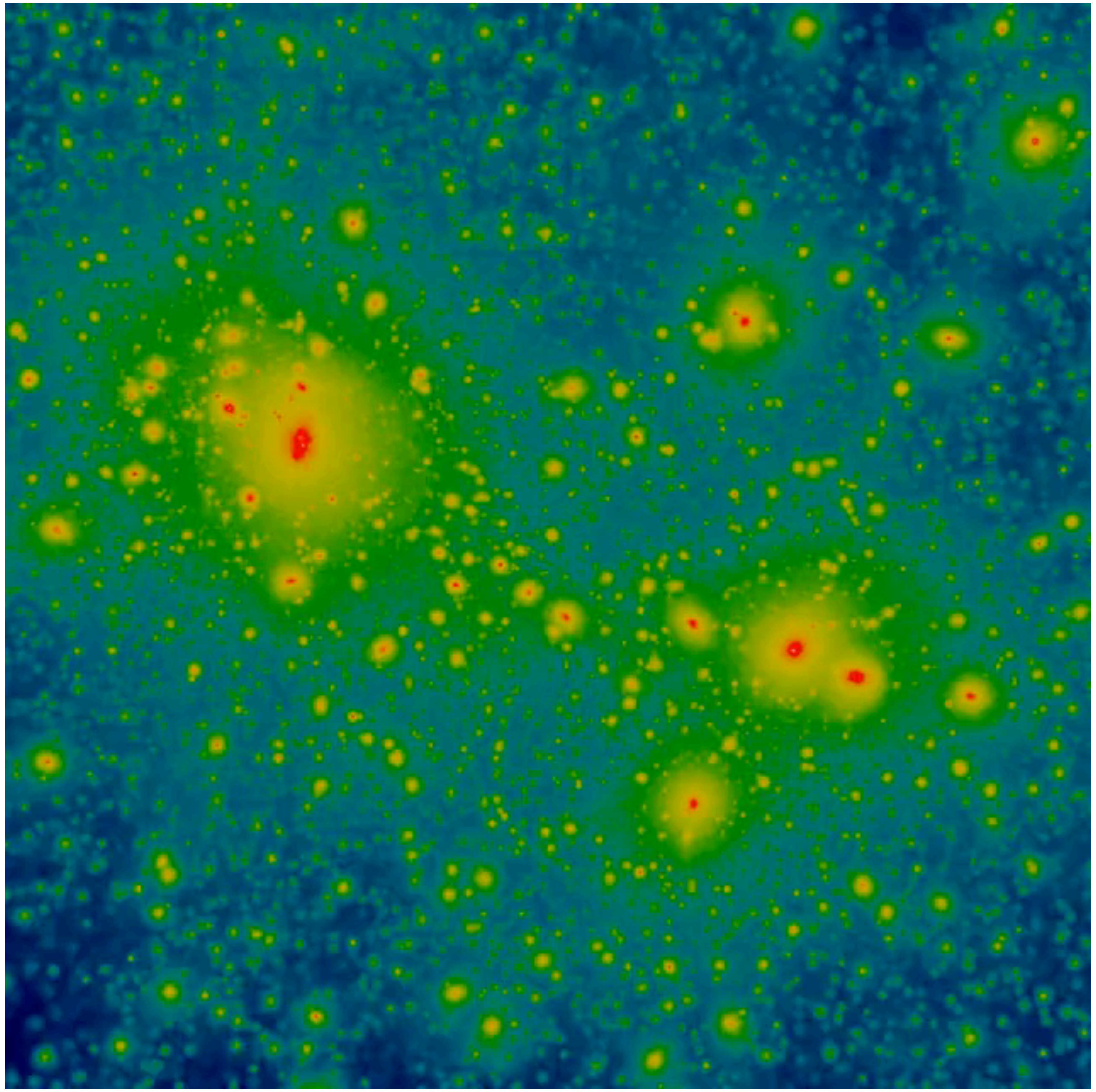
A critical scale for satellite quenching?



Possibly a critical scale for satellite quenching at ~10^8 $M_\odot$

Wheeler et al. (2014)
Phillips et al. (2015a)

Converting observed satellite quenched fractions into quenching timescales (measured relative to infall)…



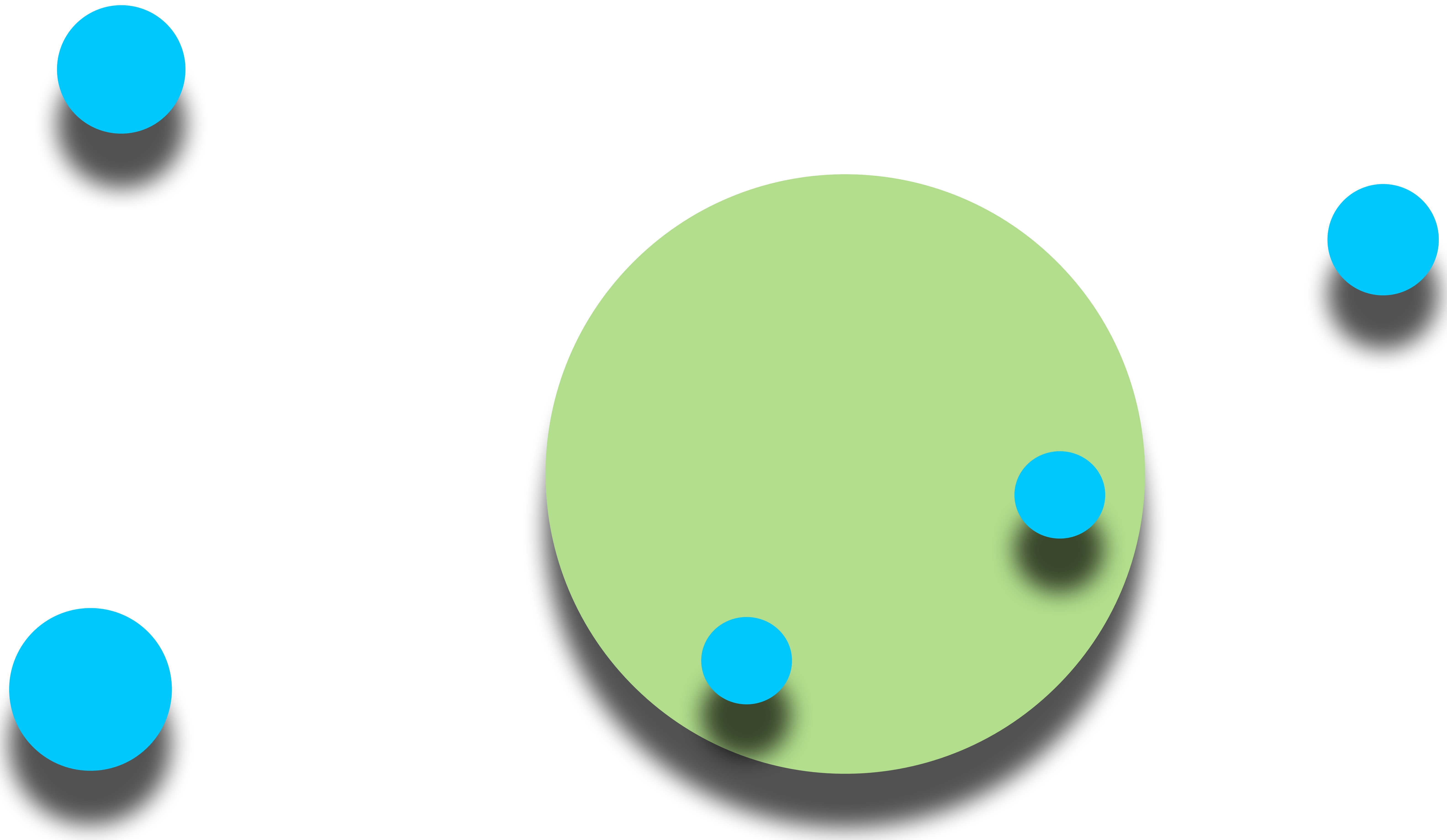
Use *N*-body simulations to constrain subhalo infall times, then tune τ_{quench} to match f_{quench} (given info for f_{quench} for the infall population).

Here, our τ_{quench} combines the “delay” and “fade” times from Wetzel et al. (2013).

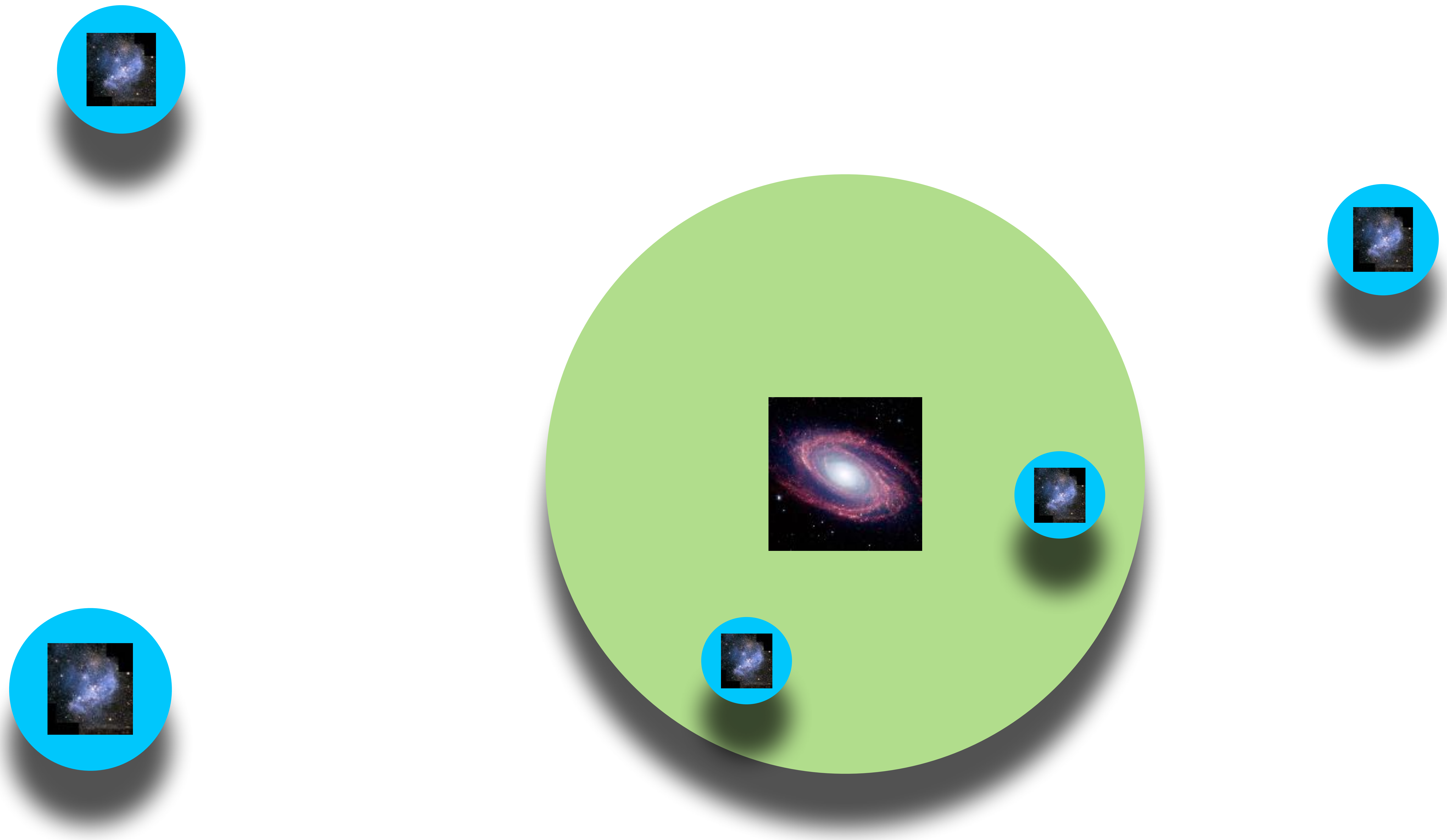
ELVIS Suite of Local Group-like halos

Garrison-Kimmel et al. (2014)

Using *N*-body Simulations to Model Satellite Quenching

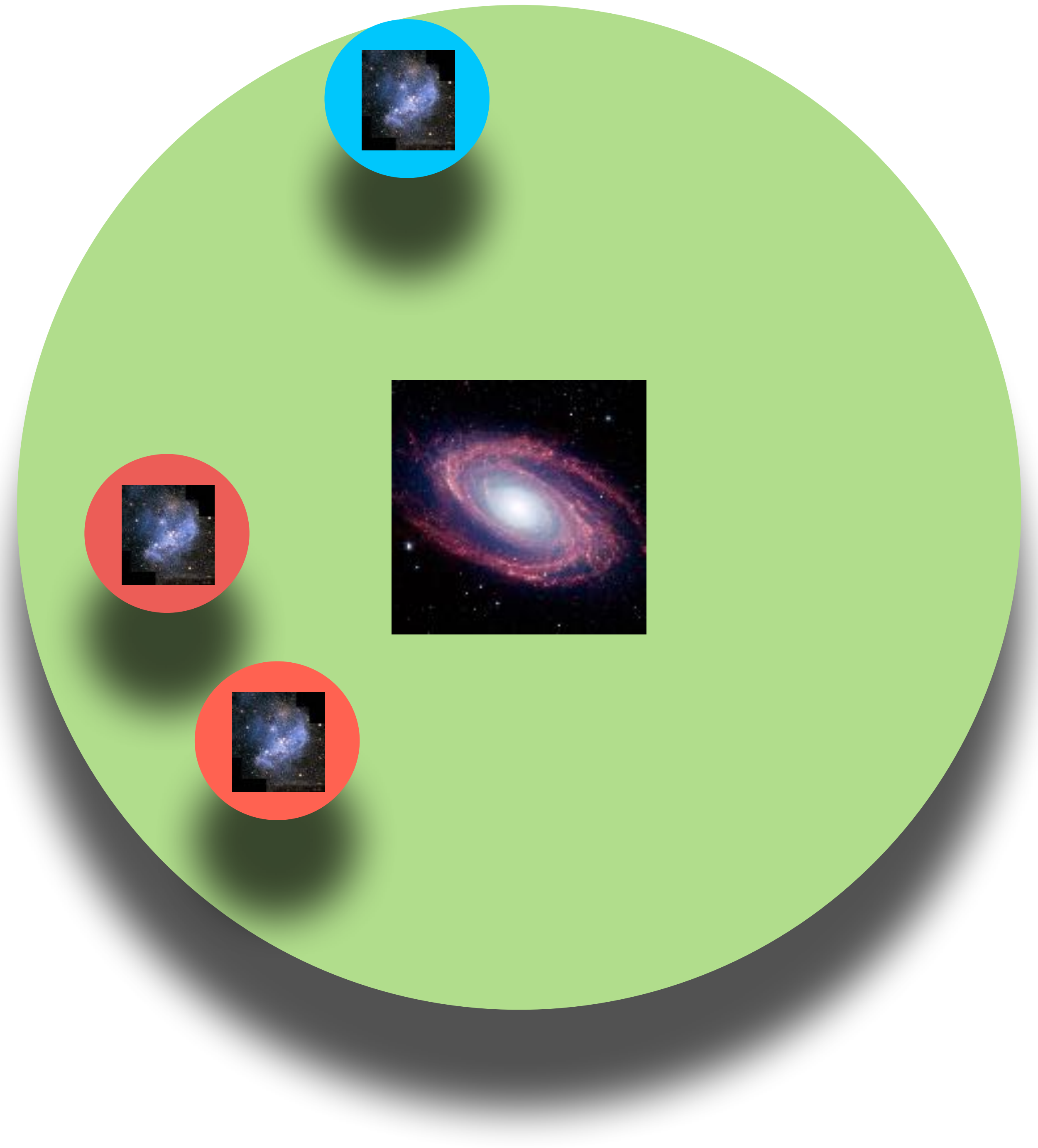


Using *N*-body Simulations to Model Satellite Quenching

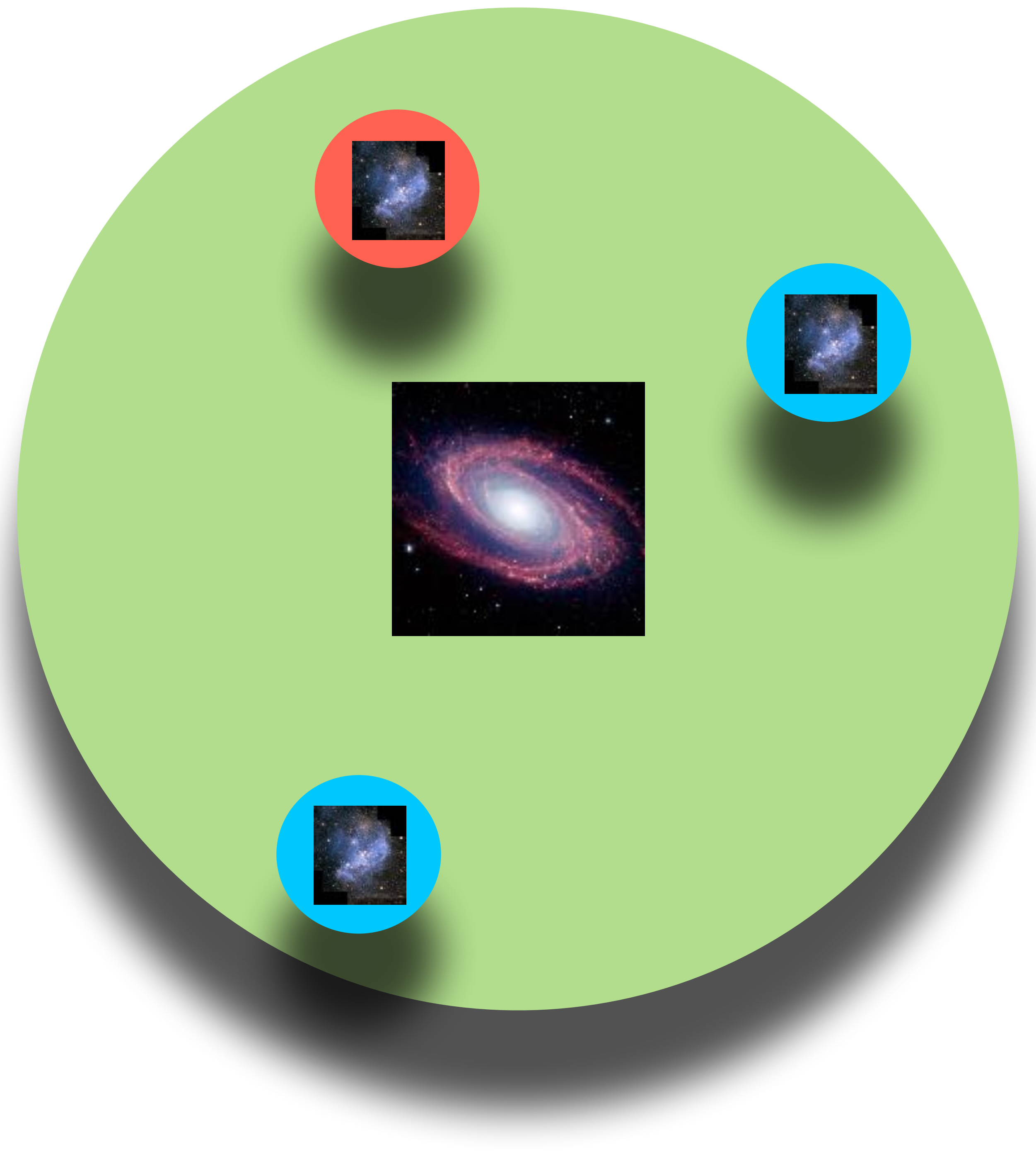


To quench satellites, we assume a quenching timescale (τ_{quench})…

τ_{quench} ~ 1 Gyr

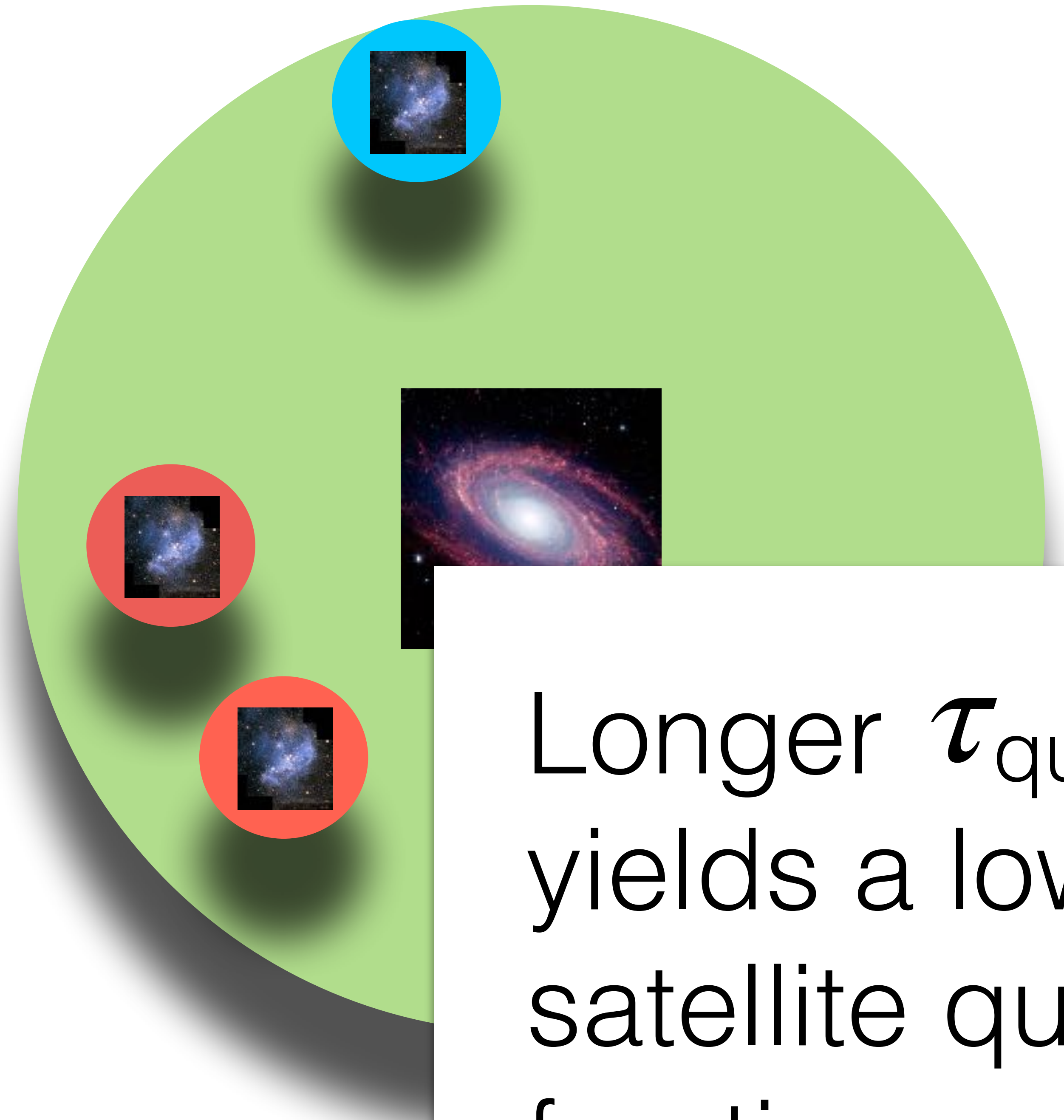


τ_{quench} ~ 4 Gyr

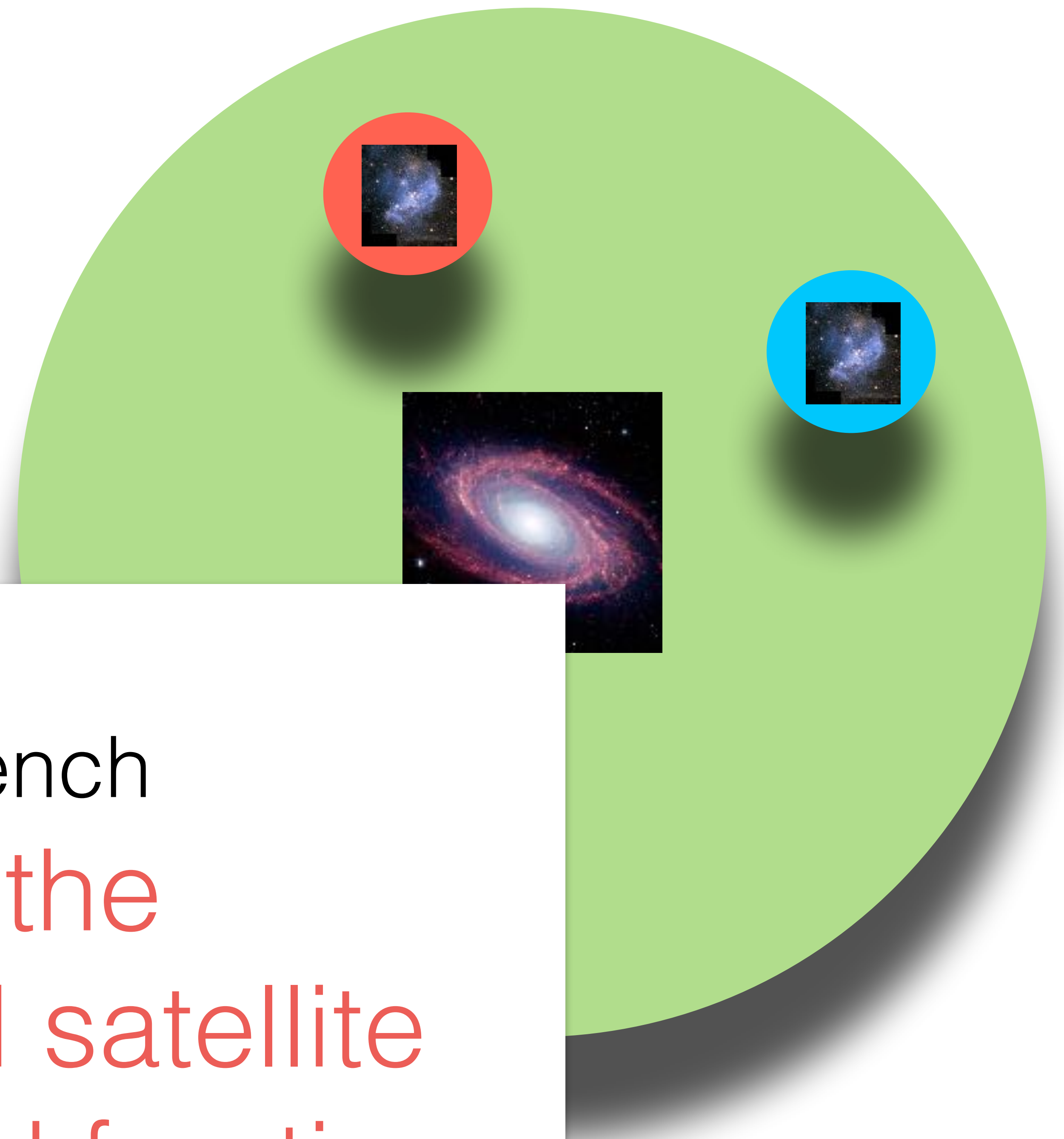


To quench satellites, we assume a quenching timescale (τ_{quench})…

τ_{quench} ~ 1 Gyr



τ_{quench} ~ 4 Gyr



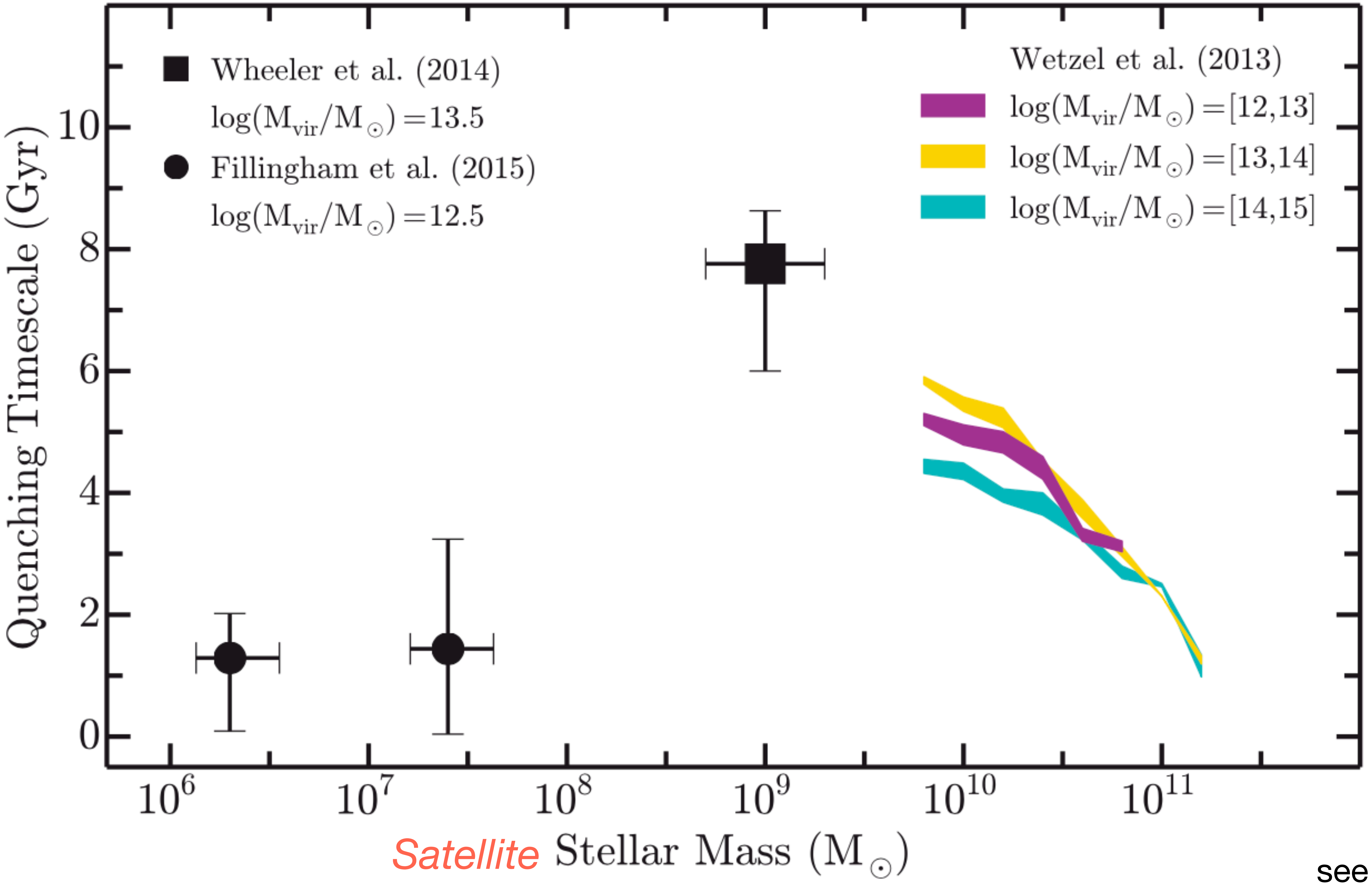
Longer τ_{quench} yields a lower satellite quenched fraction.

Tune τ_{quench} to match the observed satellite quenched fraction.

The Timescale for Satellite Quenching

TCB

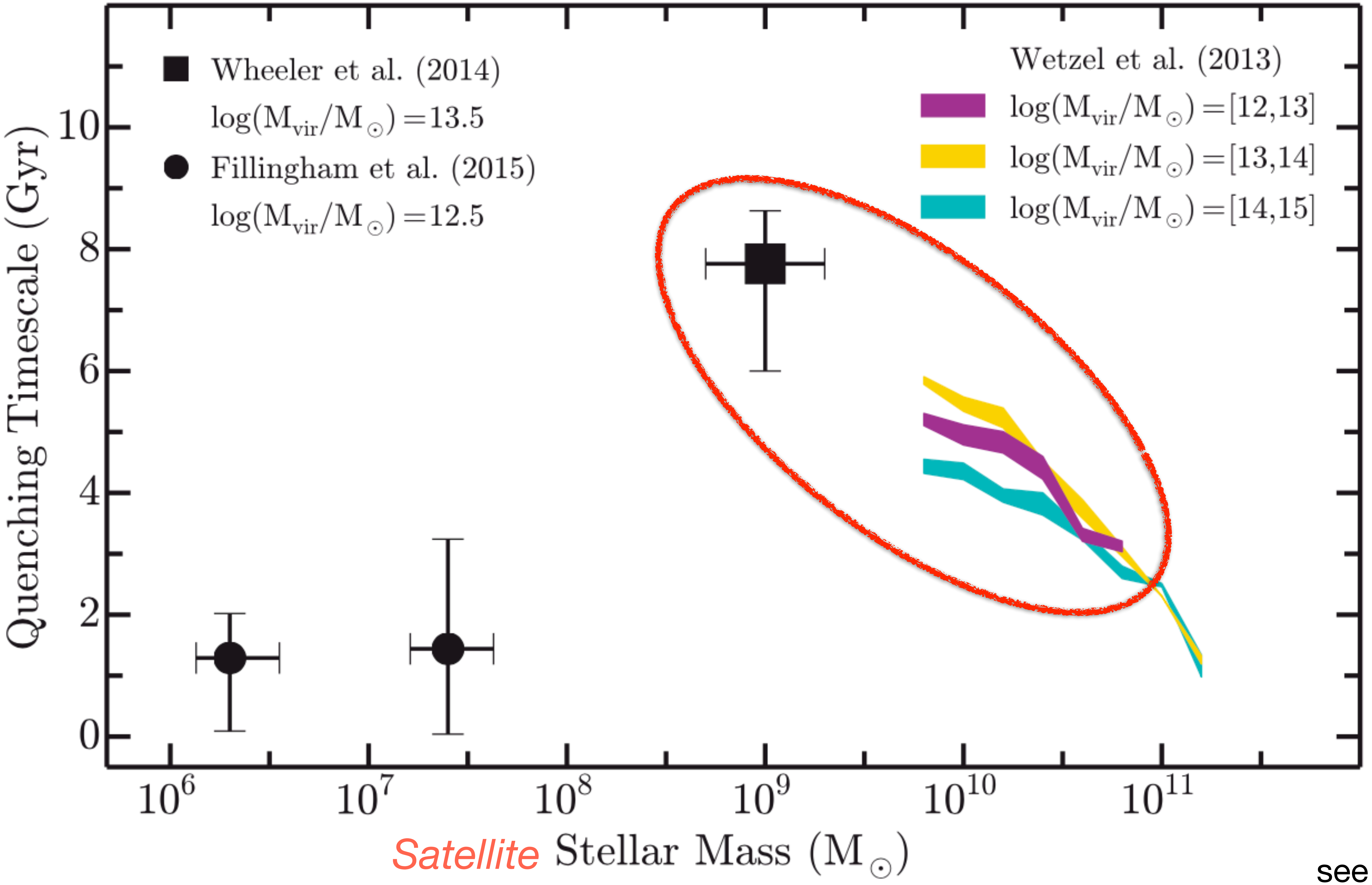
Fillingham et al. (2015, 2016)



see also Wetzel et al. (2015)

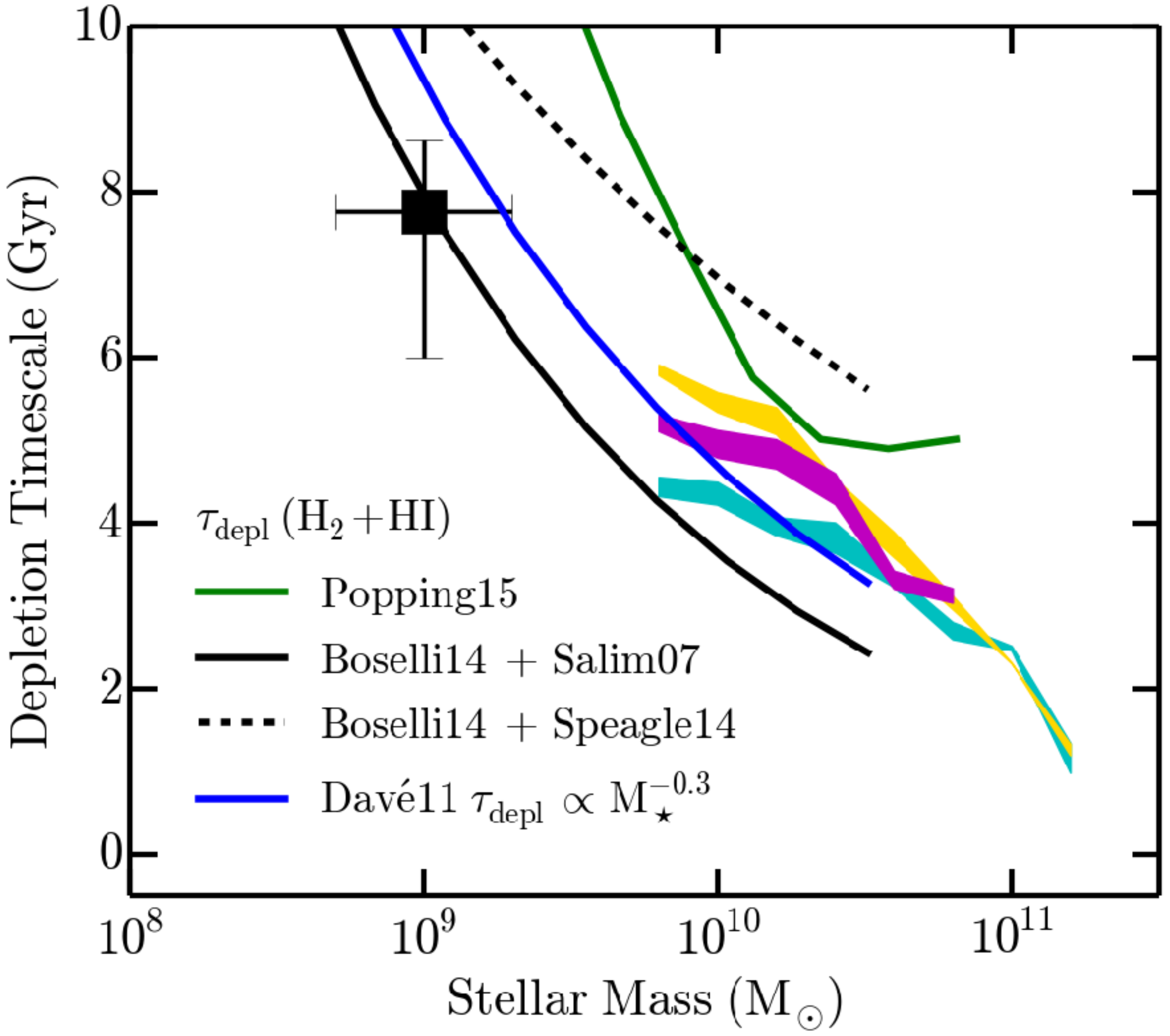
The Timescale for Satellite Quenching

Fillingham et al. (2015, 2016)



see also Wetzel et al. (2015)

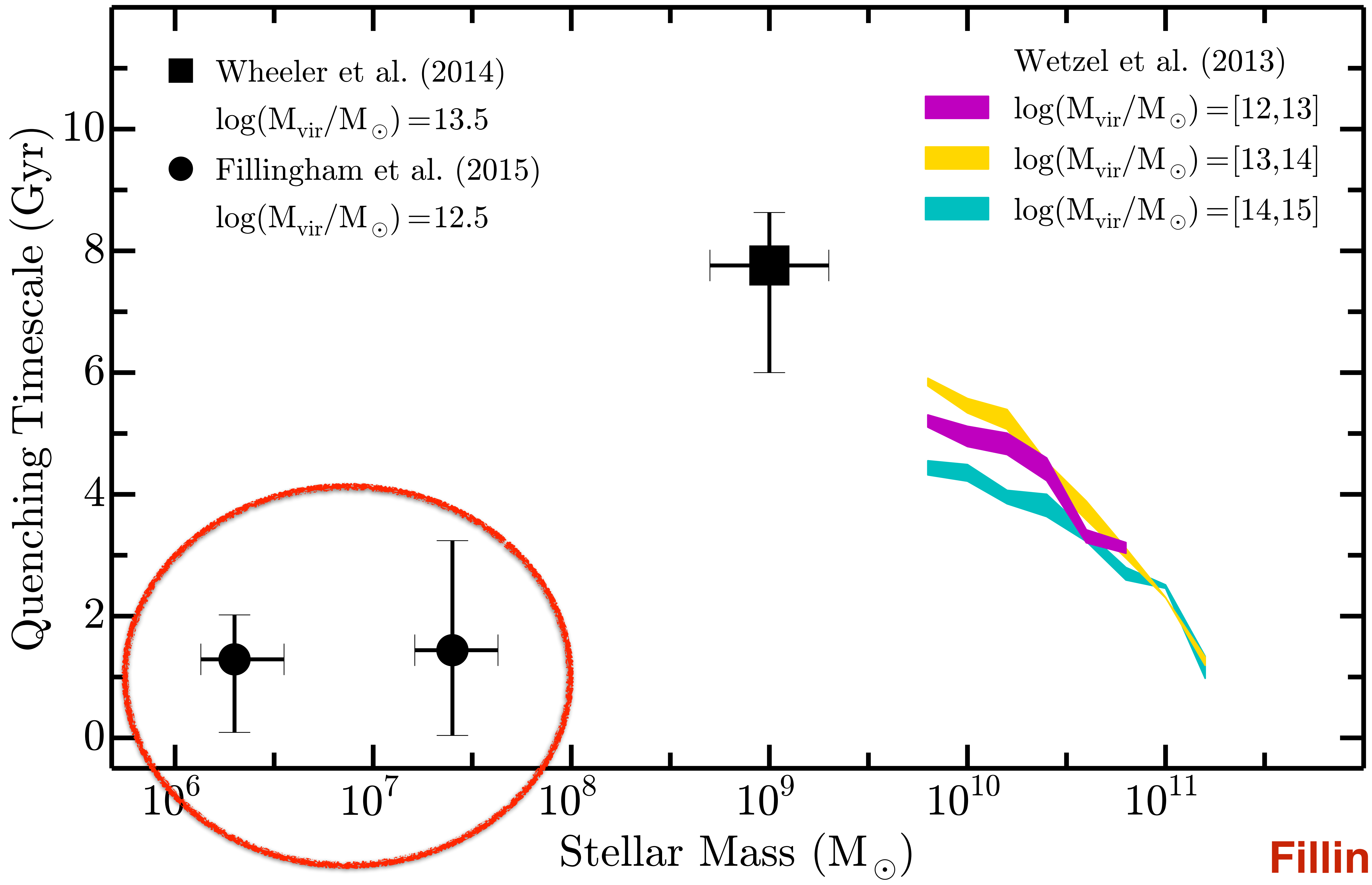
Starvation Drives Satellite Quenching at High Masses



At high satellite masses, the quenching timescale follows the cold gas (H_2 + HI) depletion timescale — as expected for starvation.

Fillingham et al. (2015)

The Timescale for Satellite Quenching



Fillingham et al. (2015)

Wetzel et al. (2013, 2015)

De Lucia et al. (2012)

What about at lower masses ($\lesssim 10^8$ M_{sun})?

Hɪ profiles of local field dwarfs with $M_\star \sim 10^6$ - 10^{10} $M_\odot$ from…

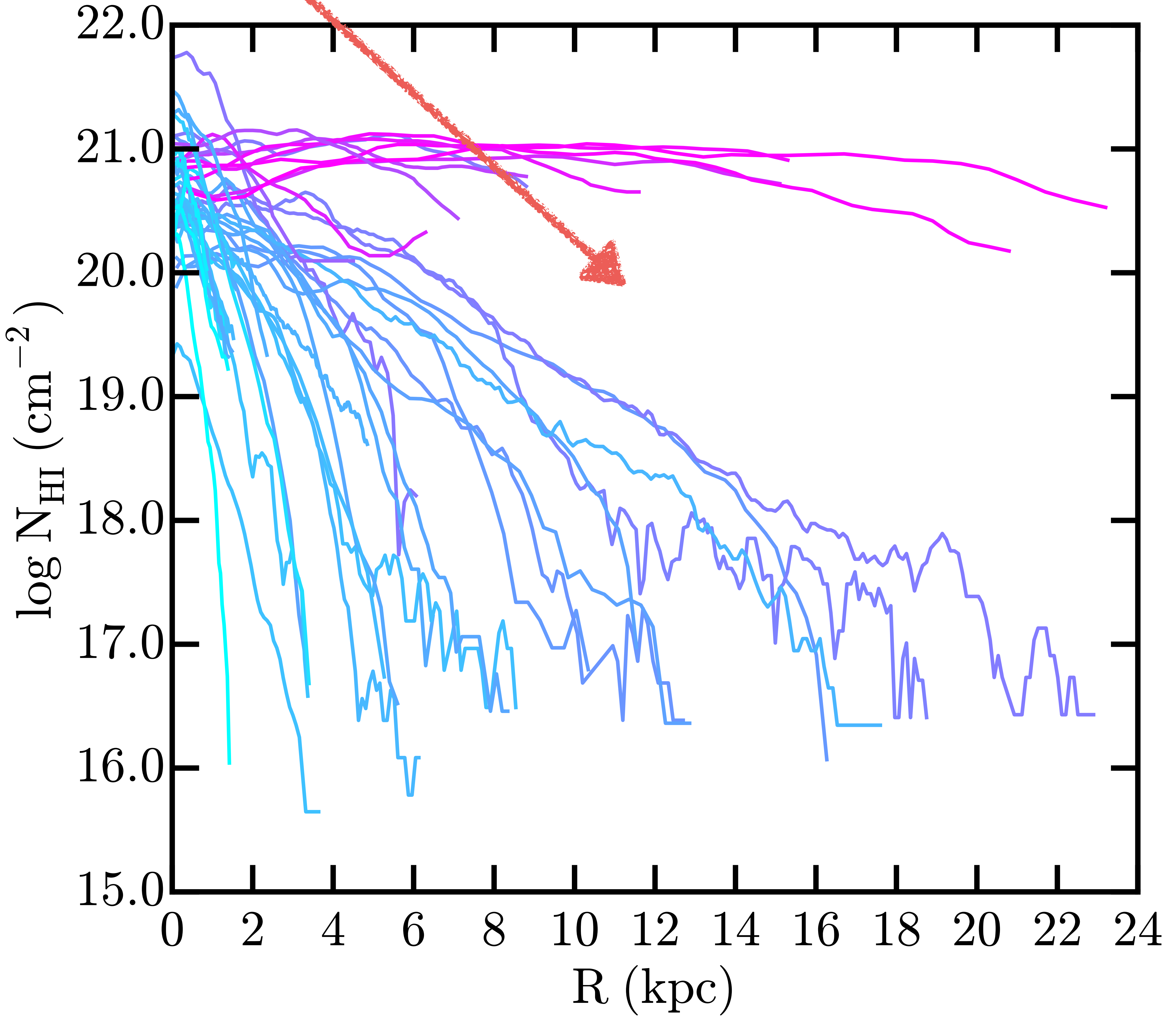
$$\rho_{halo}\, V_{infall}^2 > \frac{G\, M(<r)}{r^2}\, \Sigma_{gas}(r)$$

COS Halos measurements
$\sim 10^{-4}$ cm^{-3}

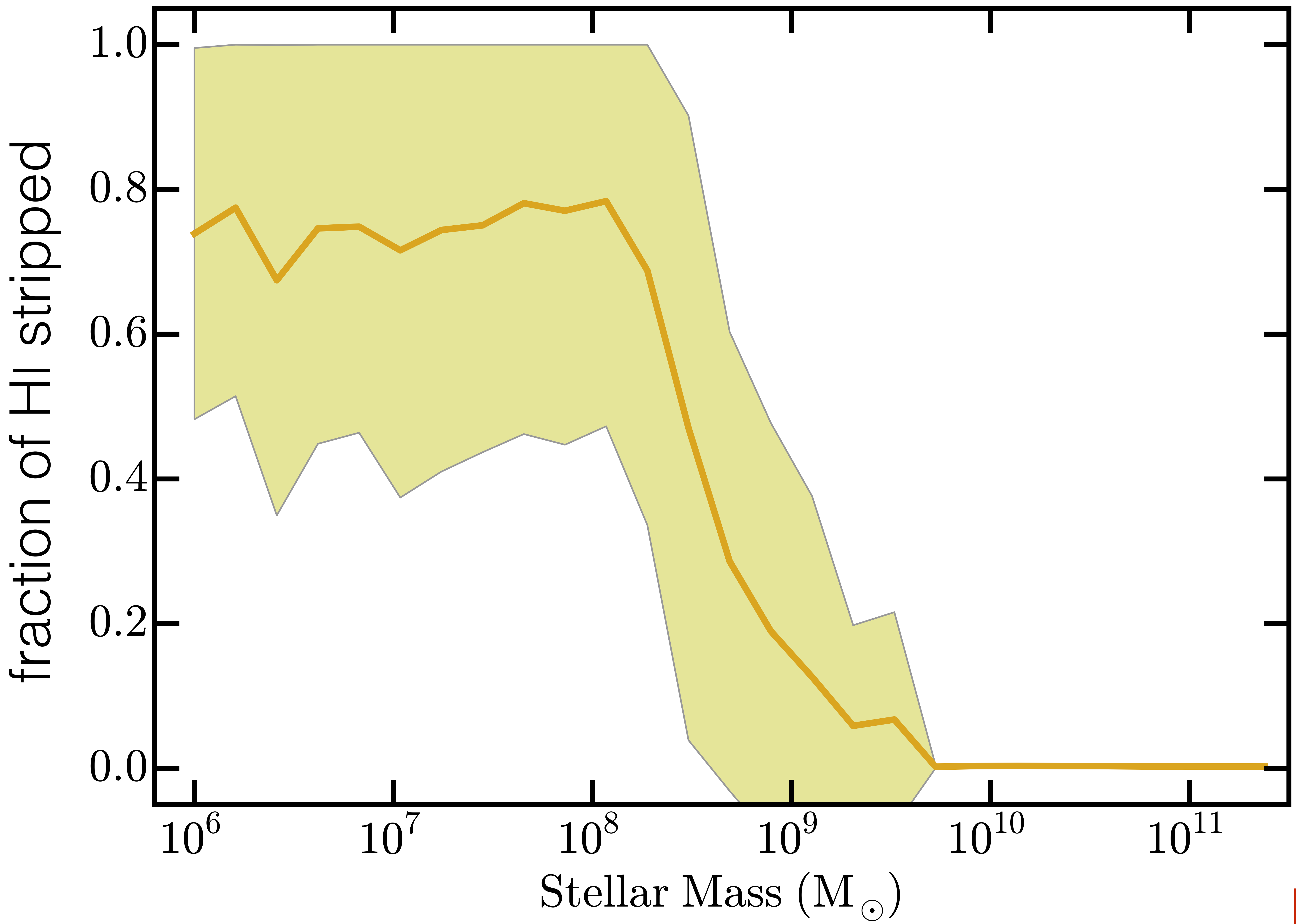
subhalo orbits in
N-body simulations

abundance matching
-or-
modeling of observed Hɪ kinematics

SHIELD (Cannon et al. 2011)
THINGS (Walter et al. 2008)
Little THINGS (Hunter et al. 2012)



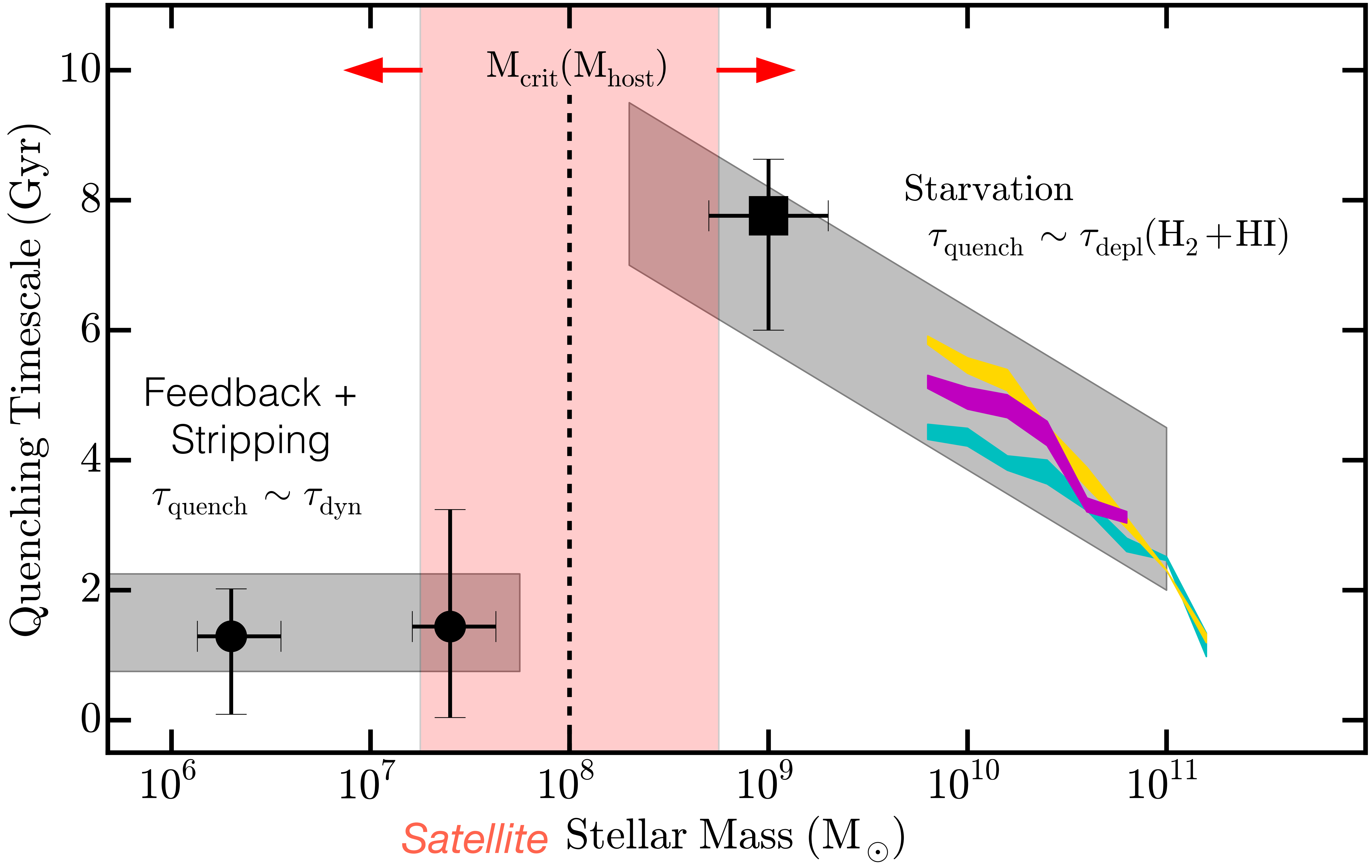
Under Pressure ⚡: Stripping reproduces the critical quenching scale at ~10^8 $M_\odot$ in Milky Way-like halos



Fillingham et al. (2016)

our simple model for satellite quenching…

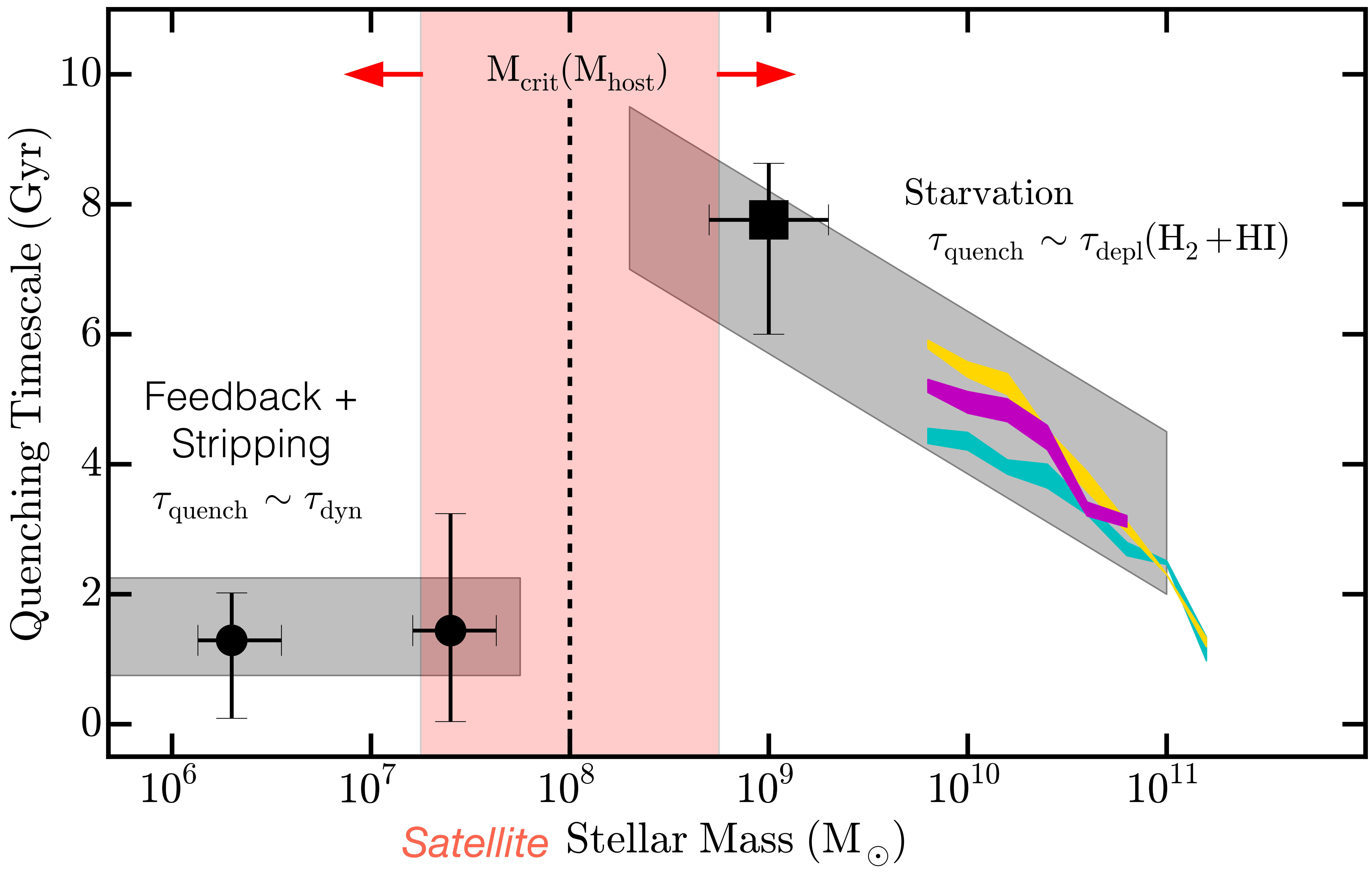
Fillingham et al. (2015, 2016)



our simple model for satellite quenching…

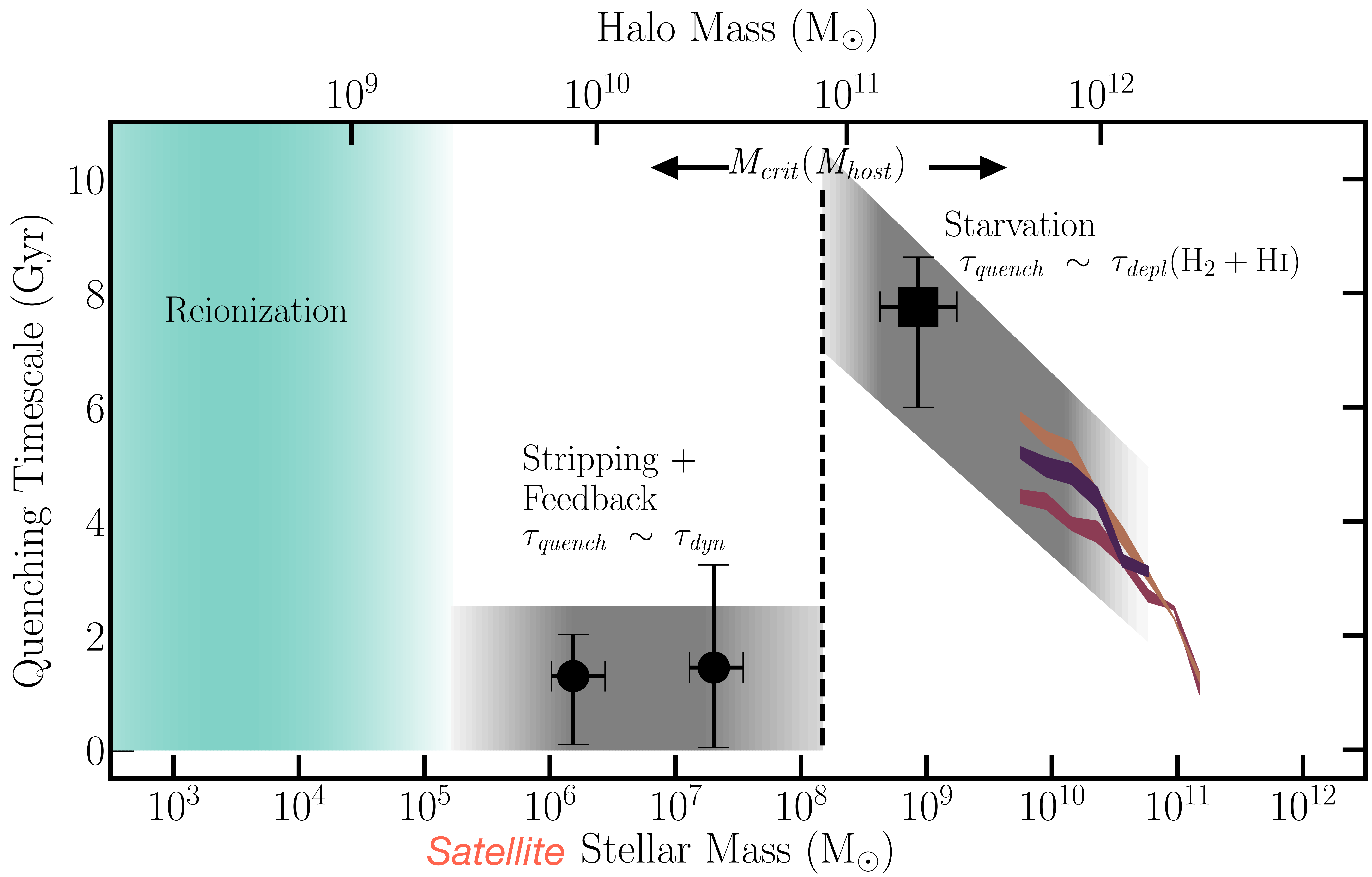
what drives quenching at the very smallest scales?

Fillingham et al. (2015, 2016)



The Timescale for Satellite Quenching

Fillingham et al. (2015, 2016)
Rodriguez Wimberly et al. (in prep)



open questions…

- ➡ is the Local Group cosmologically representative?

  (more-or-less yes, $f_{quench} \sim 0.75$ @ $M_\star < 10^8\ M_\odot$; Phillips et al. in prep)

- ➡ what about backsplash galaxies, detailed SFHs, etc.?

  (quenching model consistent with proper motions, SFHs, and local field population; Fillingham et al. in prep)

- ➡ what suppresses star formation on the smallest scales?

  (reionization, not environment; Rodriguez Wimberly et al. in prep)

- ➡ how does the quenching timescale evolve with cosmic time?

  (ongoing Keck/DEIMOS program to survey groups at $z \sim 0.8$; Fillingham et al. 2019) — also stay tuned for talk by G. Wilson

finally, a quick note regarding UDG formation…

Carleton et al. (in prep):

— use Bolshoi to constrain the orbits of subhalos in clusters (M_{halo}, V_{peri})

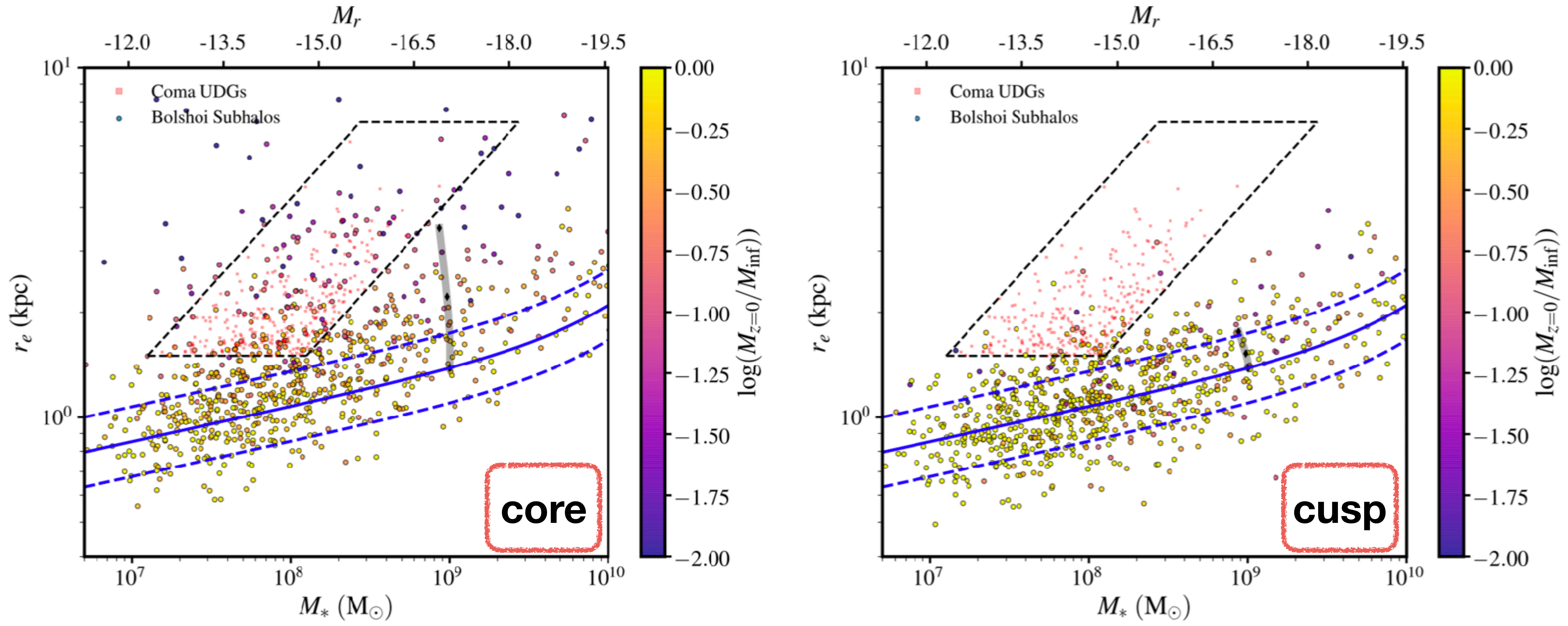
— populate subhalos assuming a $M_{\star}$-M_{halo} relation and
then adopt sizes from van der Wel (2014)

— apply an analytic model for size growth resulting from tidal stripping/heating of
low-mass halos in clusters (in both cuspy and cored halos)

➠ based on work by Raphaël Errani and Jorge Peñarruibia

finally, a quick note regarding UDG formation…

sizes and masses of our simulated dwarf populations in comparison to Yagi et al. (2016)



finally, a quick note regarding UDG formation…

⟹ UDGs are formed by tidal stripping/heating of dwarfs in cluster environments

⟹ UDGs are dwarf systems (not failed MWs), occupying ~10^{10-11} M_{sun} cored halos

our model is able to reproduce…

— the stellar mass and size distribution of UDGs

— the abundance of UDGs as a f'n of cluster mass

— the stellar ages and metallicities of UDGs