Role of environment and mergers

Bahe, Y.

THE ROLE OF ENVIRONMENT IN GALAXY FORMATION

— A VIEW FROM COSMOLOGICAL SIMULATIONS —

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Marie Skłodowska-Curie Actions
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NWO VENI
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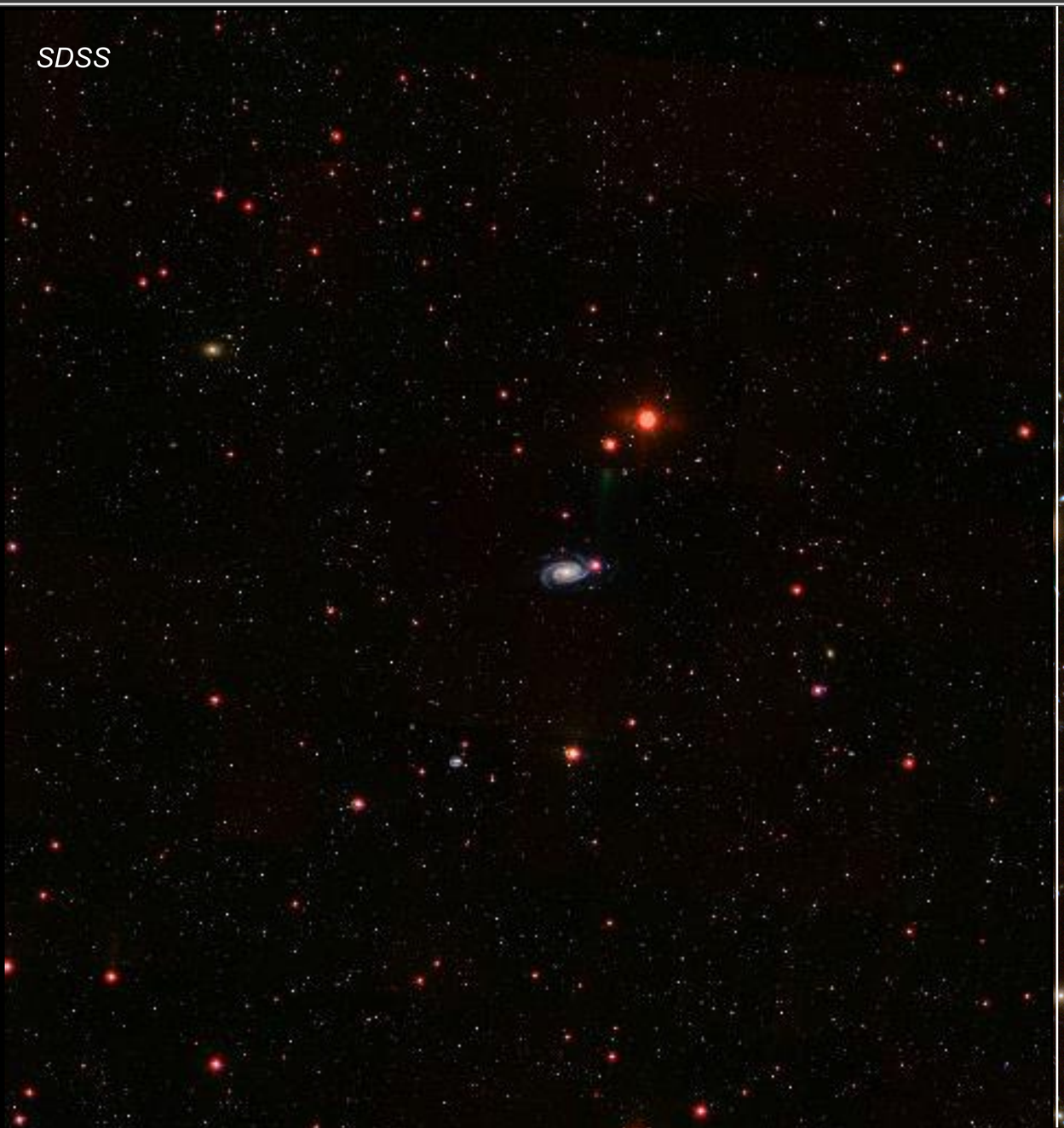
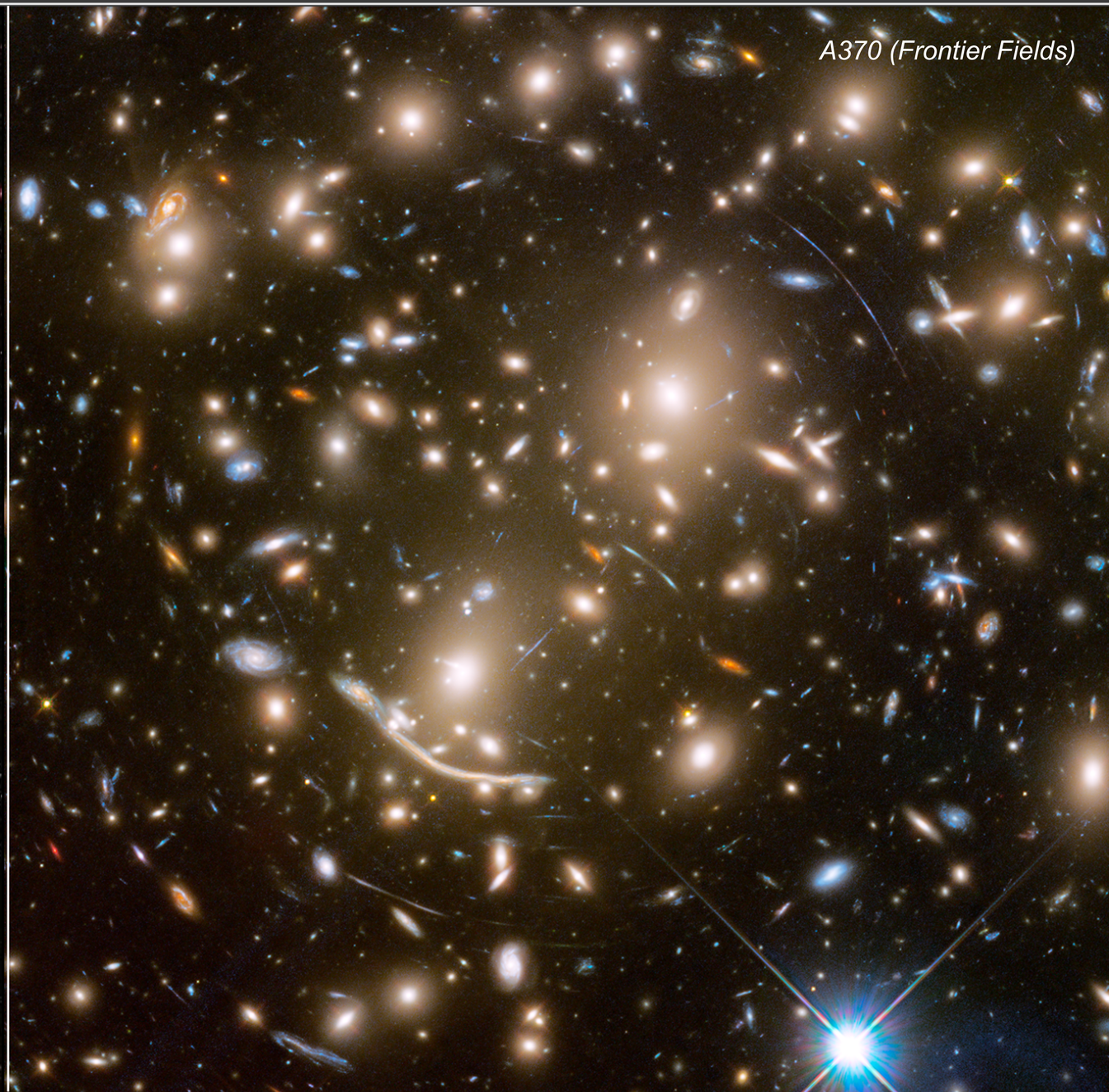
Background image: a growing galaxy cluster similar to Coma, at z = 1.5
(from the Hydrangea *simulations)*

Sydney
21 February 2019

What is "Environment"?





Observed impacts of environment on galaxies

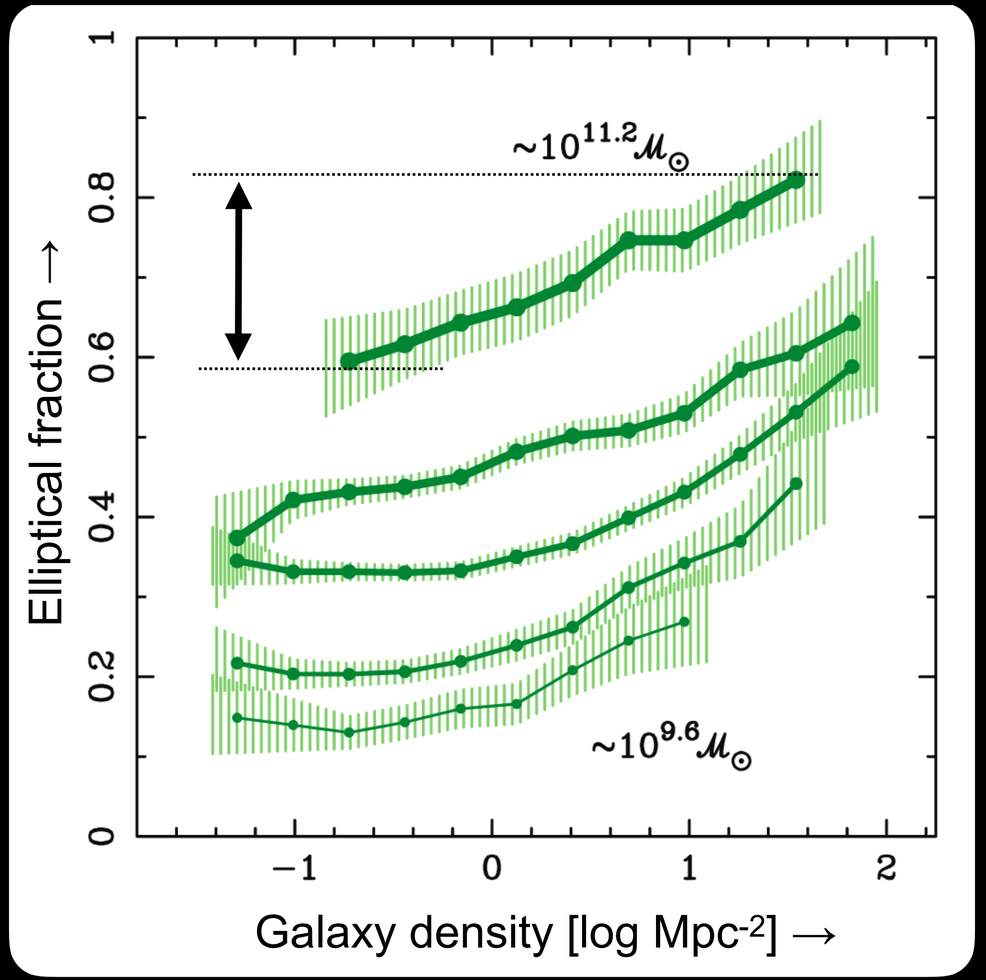
- Star formation activity / colour

  (e.g., Lewis+02, Gómez+03, Kauffmann+03, Balogh+04
  Weinmann+06, 10, v. d. Linden+10, Peng+10, 12,
  v. d. Wel+10, Prescott+11, Wetzel+12, Kovač+14,
  Wheeler+14, Davies+16, 19, Grootes+17, Schaefer+17,
  Spindler+18, Lin+19, Owers+19)

- Galaxy morphology

  (e.g., Dressler+80, Postman & Geller 84, Blanton+05,
  Bamford+09, Simard+09, Skibba+09, Weinmann+10,
  George+13, Fasano+15, Brough+17, Greene+17, Oh+18)

Elliptical fraction at fixed stellar mass
moderately affected by environment



Adapted from Bamford+09
(SDSS/Galaxy Zoo)

OBSERVED IMPACTS OF ENVIRONMENT ON GALAXIES

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- Atomic hydrogen content

  (e.g., Gavazzi+89, Solanes+01, Kenney+04, Chung+07, 09, Cortese+11, Fabello+12, Catinella+13, Hess & Wilcots 13, Jaffé+15, Brown+17, Burchett+18, Crone Odekon+18)

- Galaxy sizes (?)

  (e.g., Weinmann+09, Rettura+10, Valentinuzzi+10, Cooper+12, Papovich+12, Poggianti+13, Newman+14, Matharu+19)

- Galaxy metallicity

  (e.g., Cooper+08, Ellison+09, Pasquali+10, 12, Petropoulou+12, Lopes+16, Maier+19)

- Reduced X-ray haloes of galaxies

  (e.g., Sun+07, Mulchaey & Jeltema 10, Rasmussen+12, Eckert+17)

- (Generally) suppressed AGN activity

  (e.g., Kauffmann+03, Pasquali+09, Silverman+09, v. d. Linden+10, Pimbblet+13, Jiang+16, Lopes+17, Poggianti+17, Li+19)

- Higher stellar/DM mass ratio

  (e.g., Gillis+13, Niemiec+17, Sifón+18)

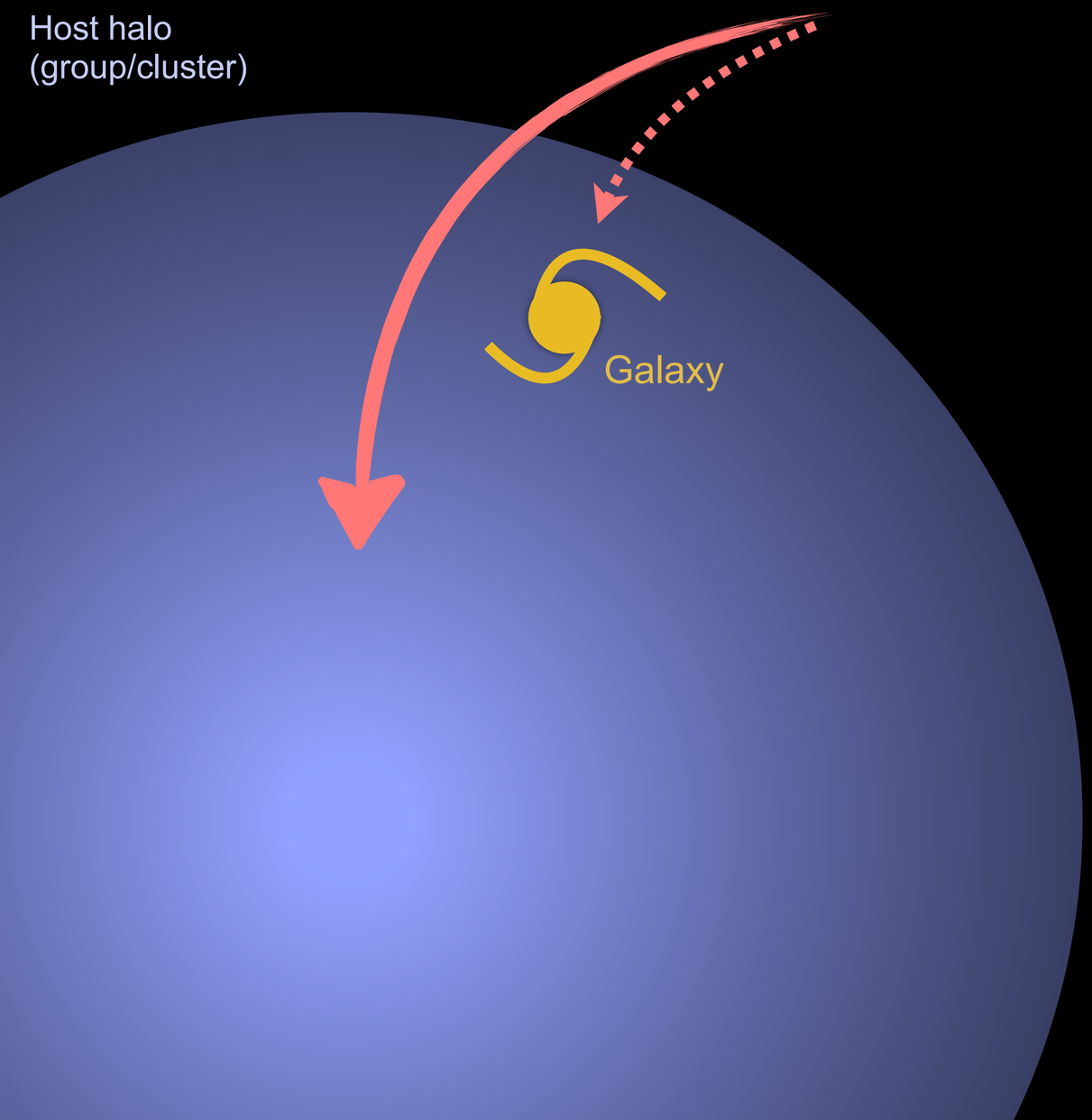
Influence of environment extends beyond massive clusters or the halo virial radius

(e.g., Balogh+99, Ellison+09, v. d. Linden+10, Lu+10, Wetzel+12, Catinella+13, Crone Odekon+18, Vulcani+18)

Influence of environment persists to $z \gg 0$

(e.g., Cooper+10, Vulcani+10, McGee+11, Giodini+12, Quadri+12, Bassett+13, v. d. Burg+13, Mok+13, Kovač+14, De Propris+15, Balogh+16, Fossati+17, Kawinwanichakij+17, Nantais+17, v. d. Burg+18, Galametz+18, Papovich+18, Tomczak+19)

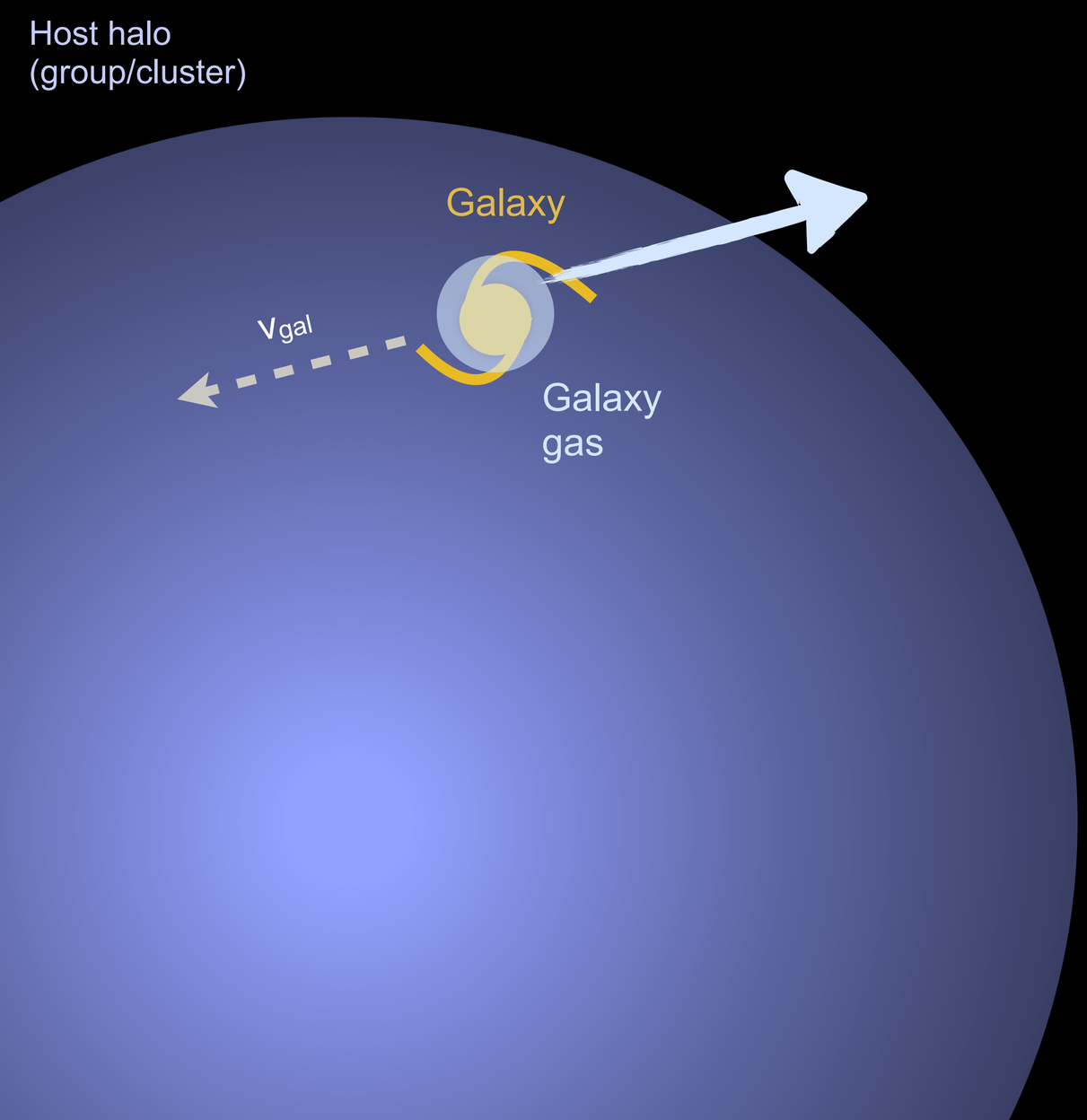
Mechanisms for environmental transformation



Suppression/stop of cosmic accretion (gas, DM)

e.g., Behroozi+14, YMB+15, v. d. Voort+17, Joshi+19

MECHANISMS FOR ENVIRONMENTAL TRANSFORMATION



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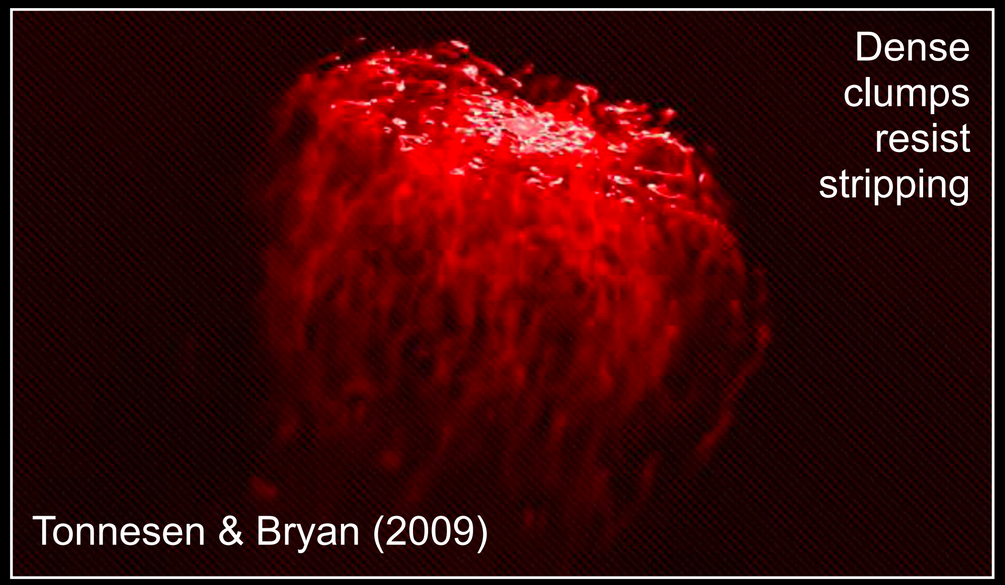
Ram pressure stripping (especially hot/tenuous gas)

e.g., Gunn & Gott 72, Larson+80, Abadi+99, Balogh+00, Roediger & Brüggen 07, Tonnesen & Bryan 07, 08, 09, Chung+07, 09, Kawata & Mulchaey 08,McCarthy+08, Smith+10, Steinhauser+16, Fossati+16, Poggianti+16, 17



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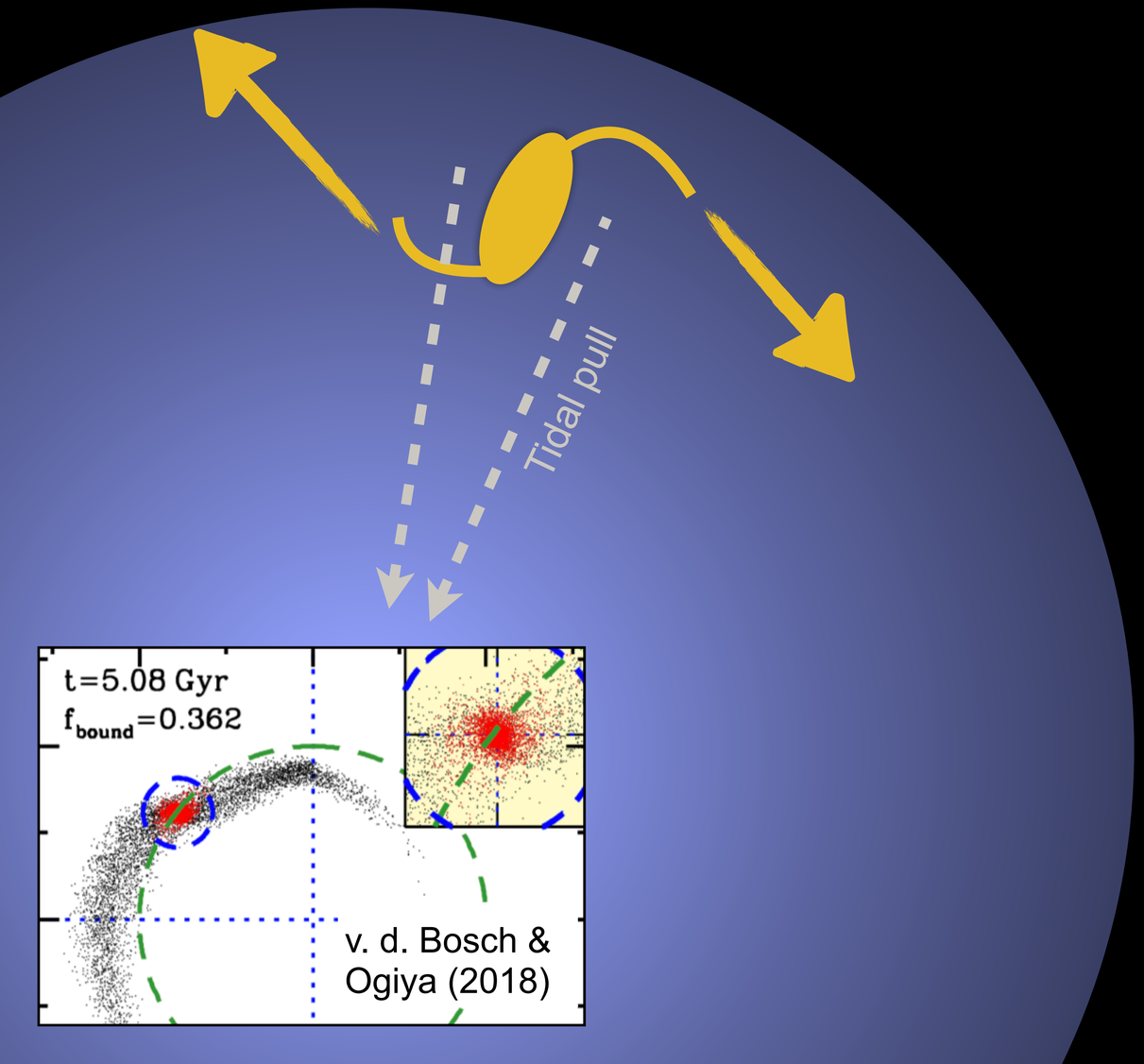

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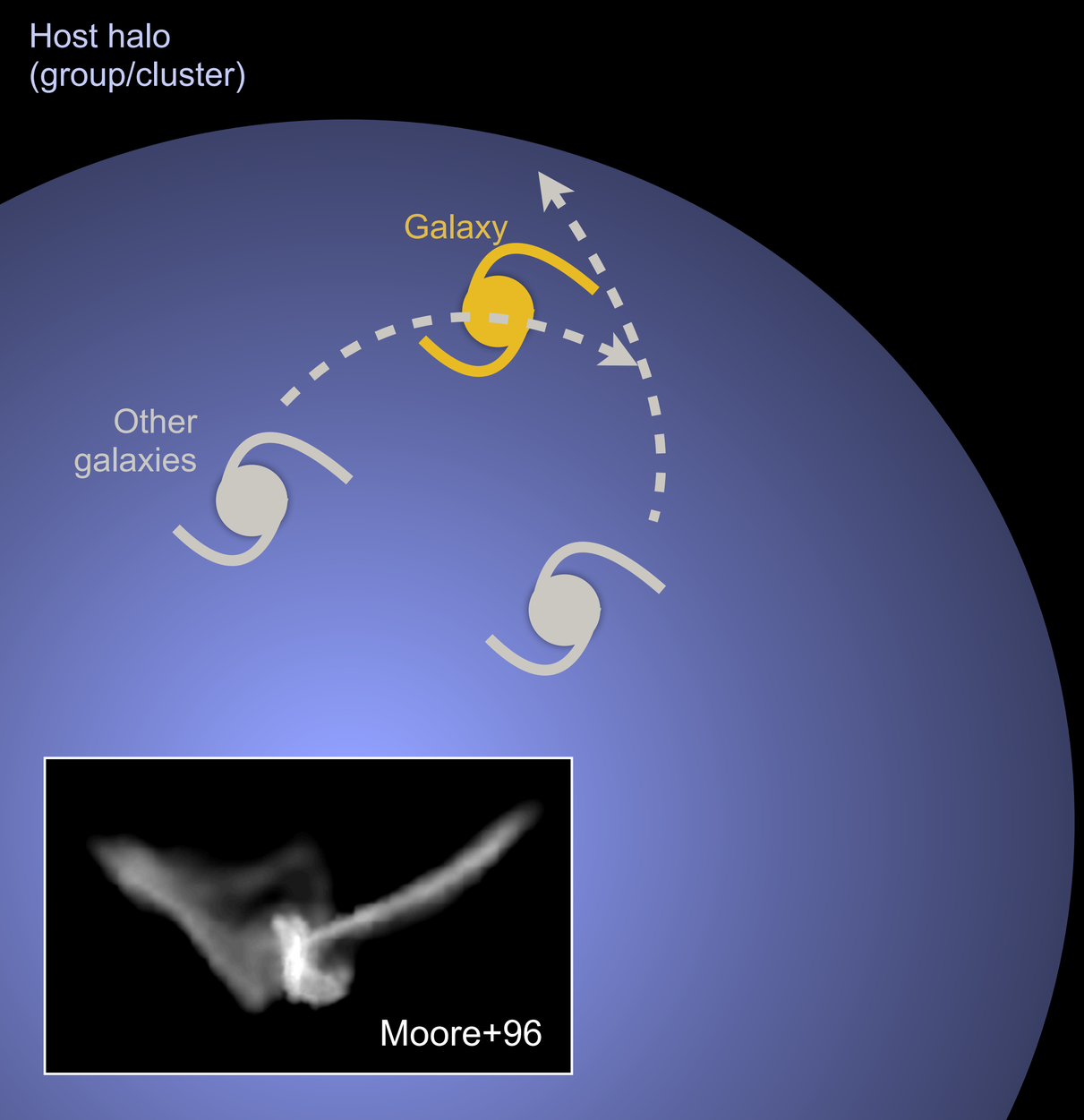
Tidal stripping of galactic matter

e.g., Merritt 83, Tormen+98, Moore+99, Hayashi+03, De Lucia+ 04, Gao+04, Xie & Gao 15, v. d. Bosch+17, Joshi+17, 19, Niemiec+18, v. d. Bosch & Ogiya 18, Ogiya+19

Mechanisms for environmental transformation



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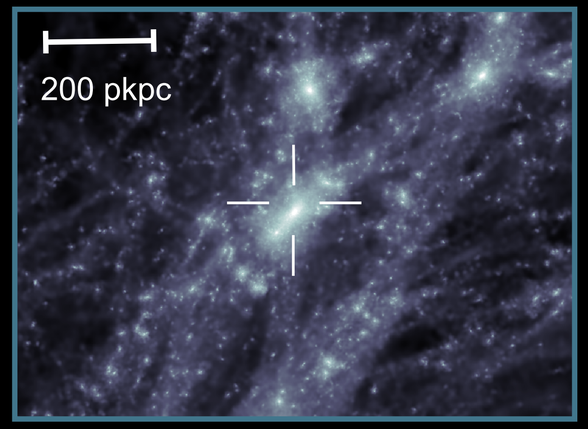
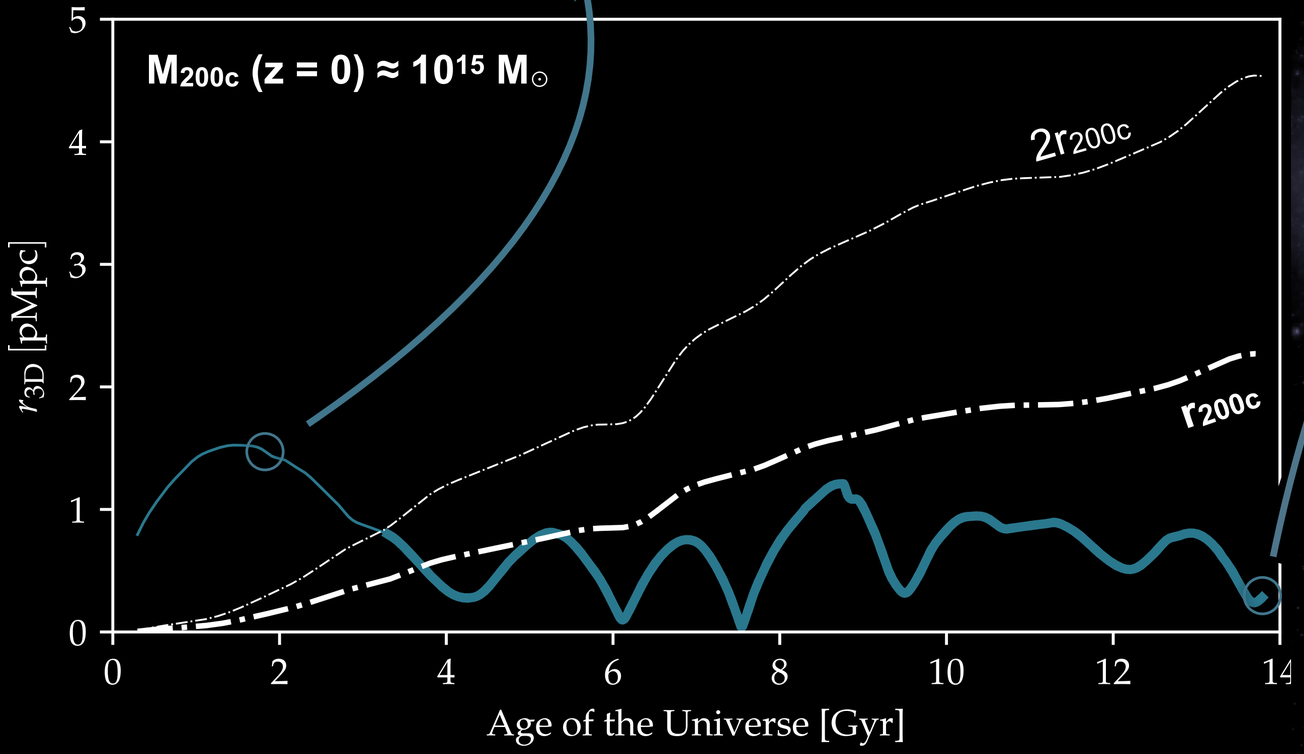
Repeated encounters with other satellites (“harassment")

e.g., Moore+96, 98, 99, Murante+07, Smith+10, Villalobos+14, Smith+15, Bialas+16, Marasco+16

INFALL OF SATELLITE GALAXIES

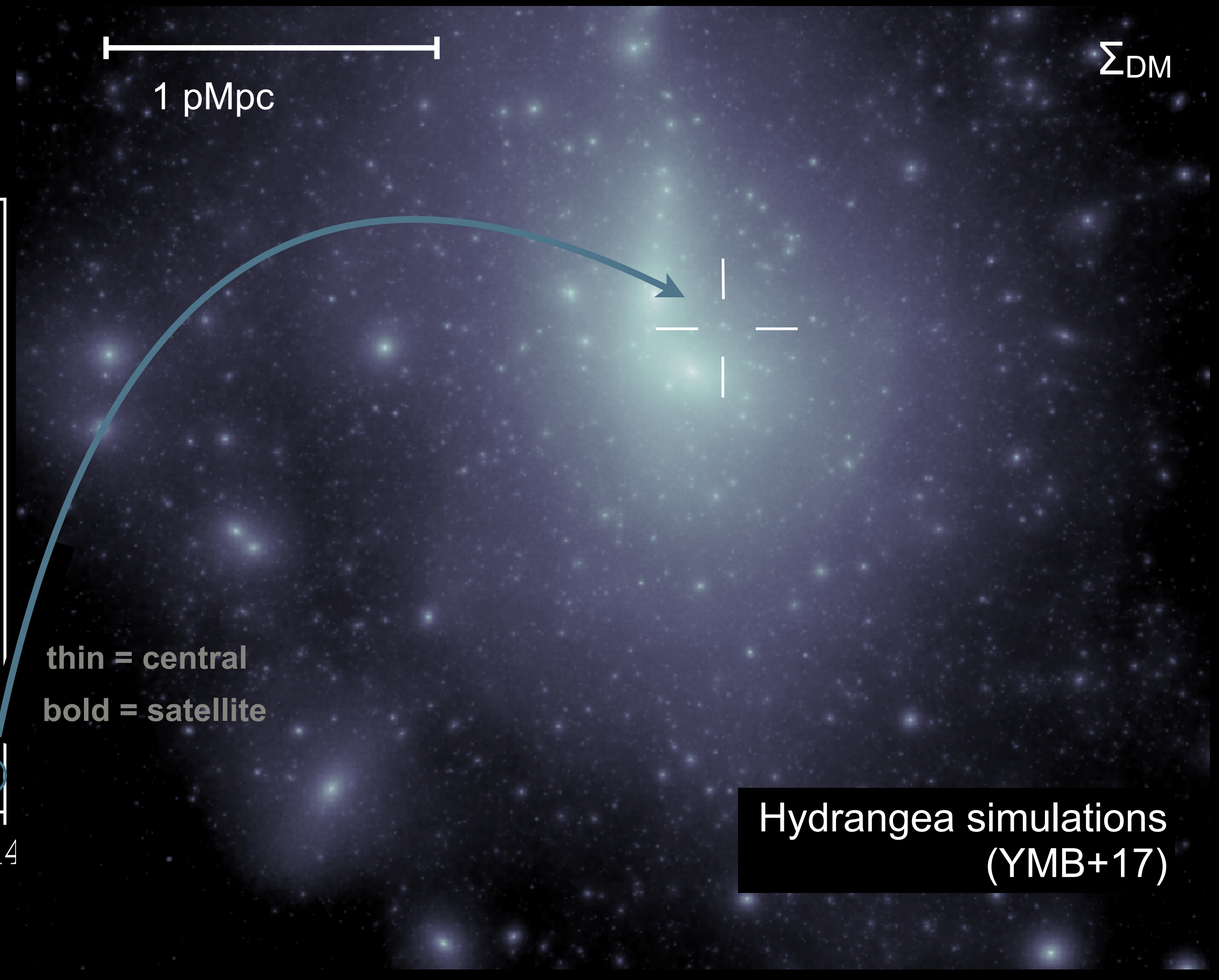
[SKIPPED IN TALK]





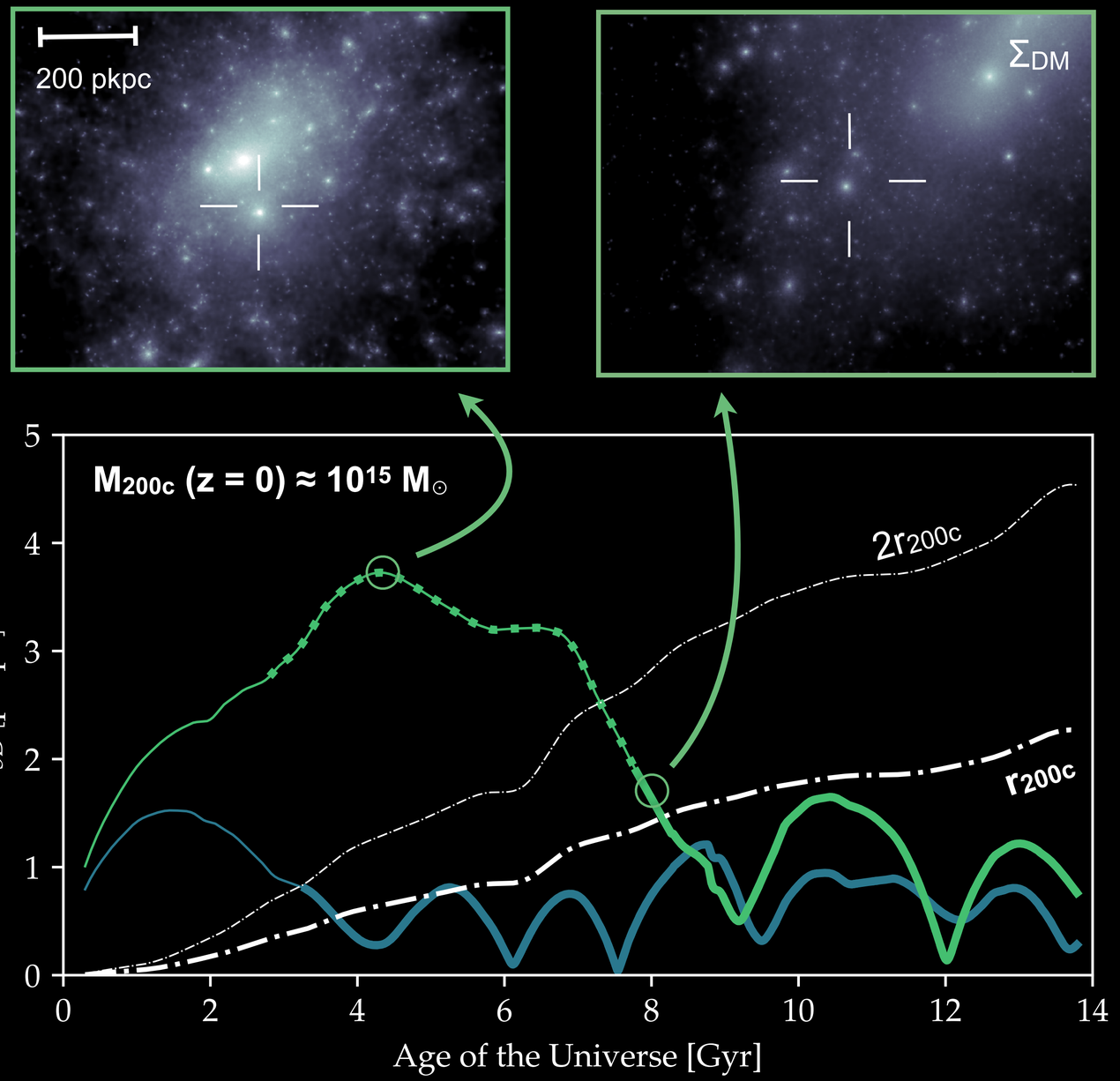
Infall of initially isolated haloes from several (p)Mpc

e.g., Press & Schechter 74, Davies+85, Bond+91, Li+08, Berrier+09, McGee+09



INFALL OF SATELLITE GALAXIES

[SKIPPED IN TALK]



thin = central

bold = satellite

bold dotted = pre-processing

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Pre-processing in infalling group haloes

e.g., Fujita 04, Cortese+06, Berrier+09, McGee+09, Simha+09, De Lucia+12, YMB+13, Wetzel+13, Hou+14, Bianconi+18, Han+18, YMB+19, Gupta+19,

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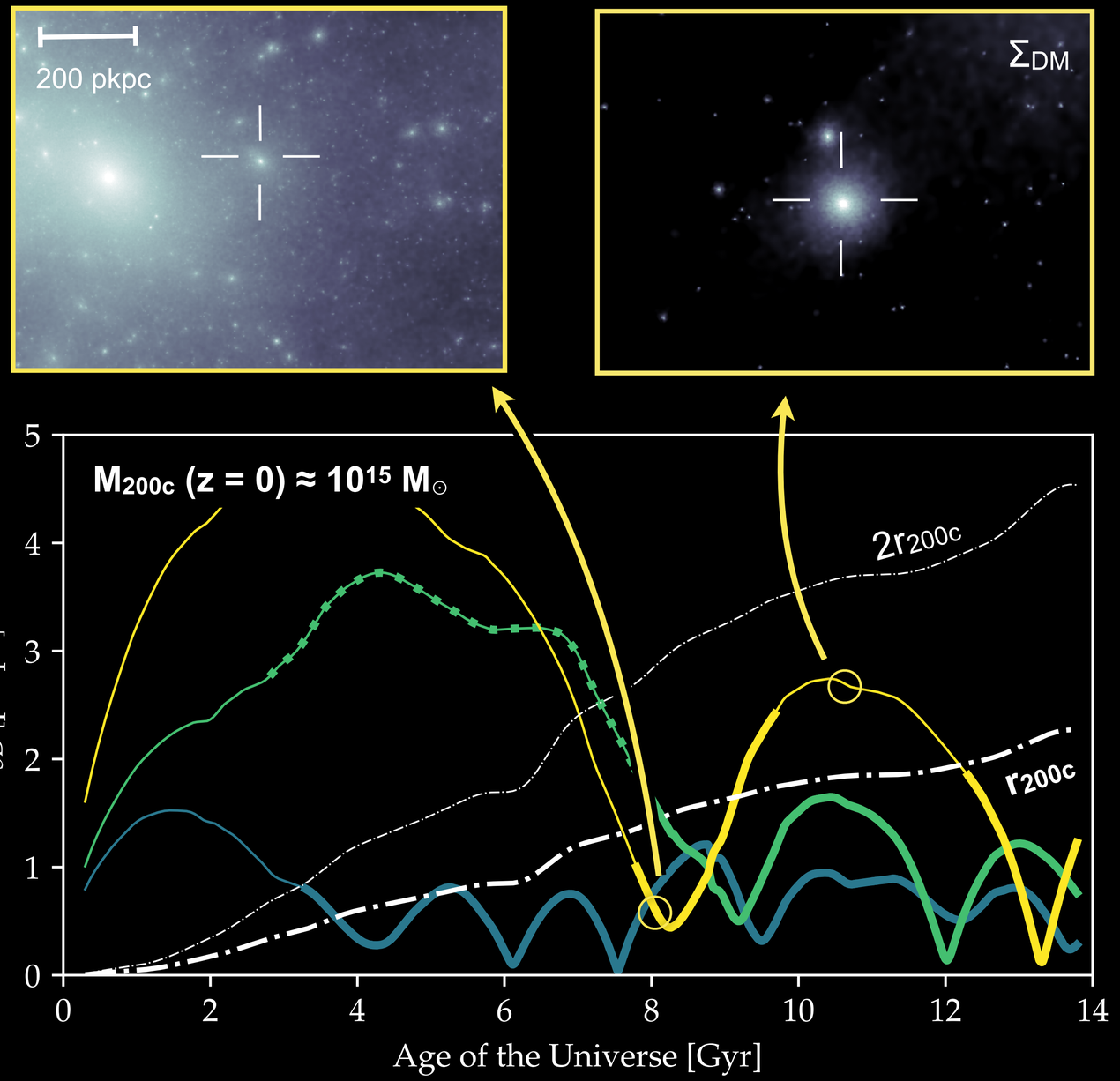

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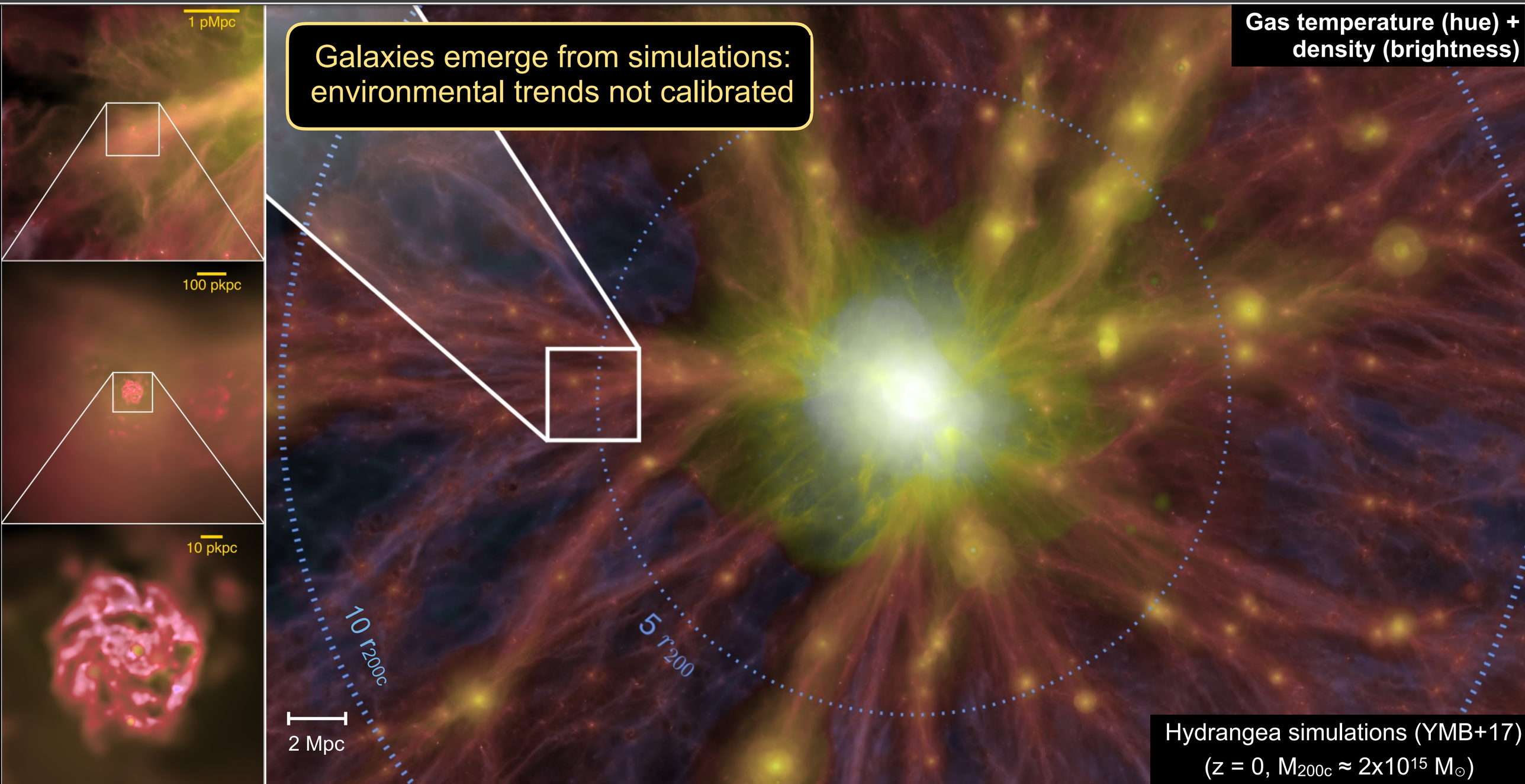
Galaxy “backsplash"

e.g., Balogh+00, Gill+05, Sales+07, Ludlow+09, Knebe+12, Teyssier+12, YMB+13, Wetzel+13, 14, Buck+19

Explains (mostly) environmental influence beyond r_{200}

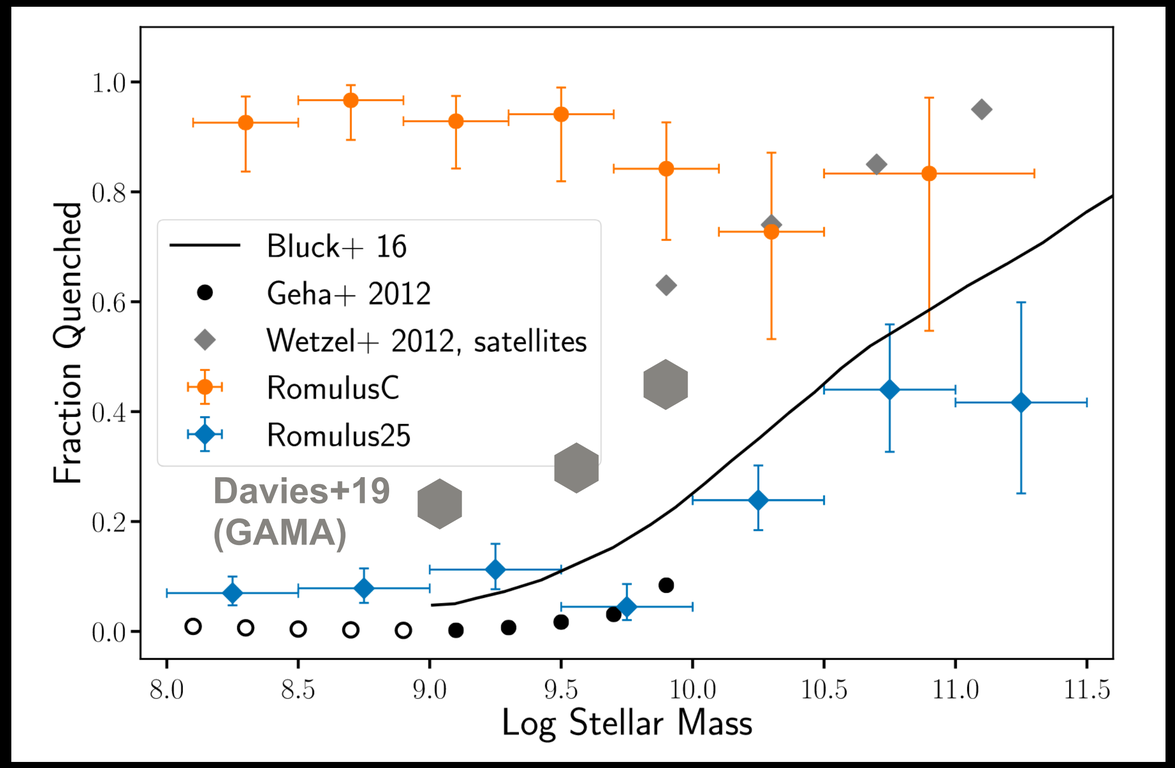
(YMB+13)

COSMOLOGICAL HYDRO-SIMULATIONS AND ENVIRONMENT



Cosmological simulations and environment

Quenched galaxy fractions

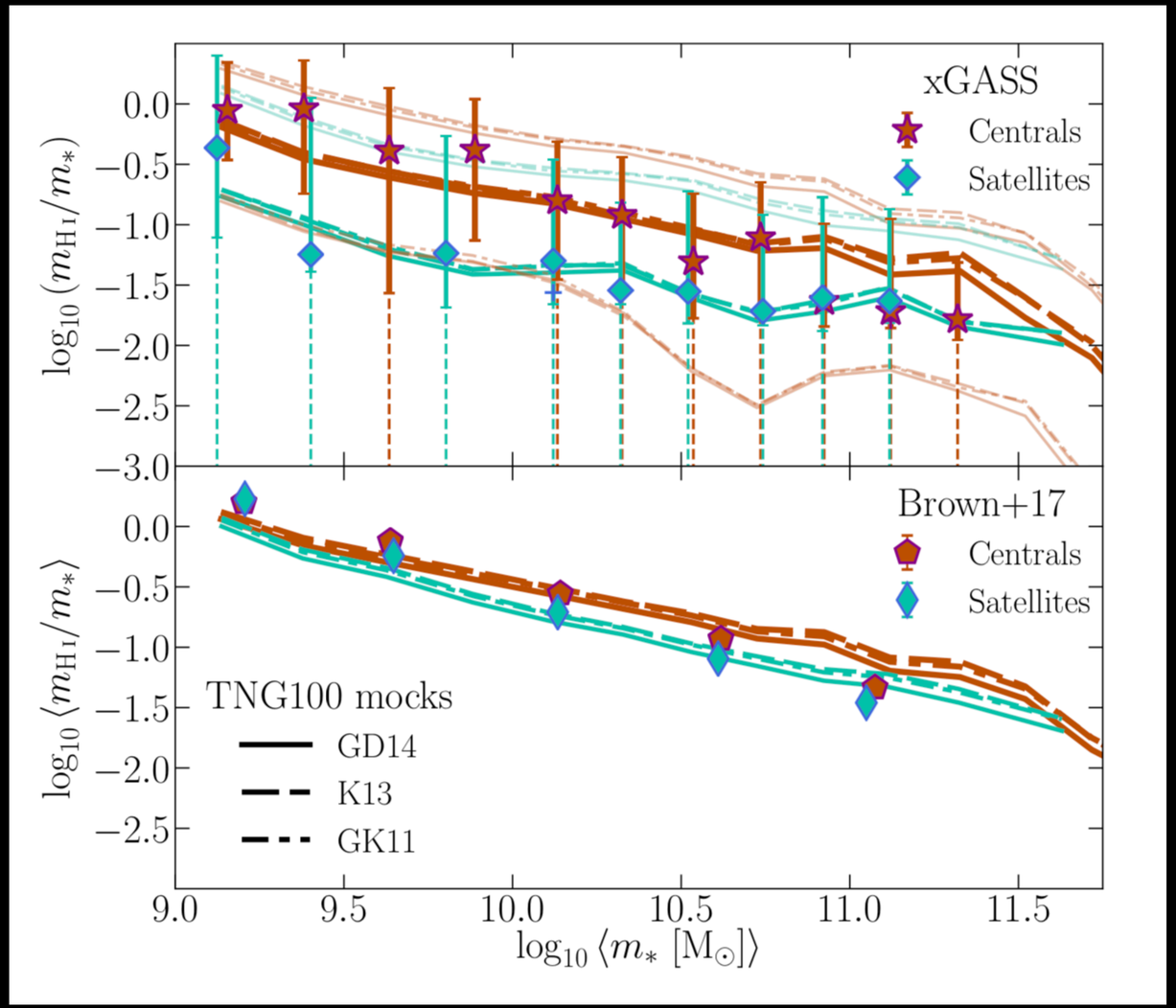


Adapted from Tremmel+19 (RomulusC)

Simulations agree reasonably with observations, better for HI than quenched fractions

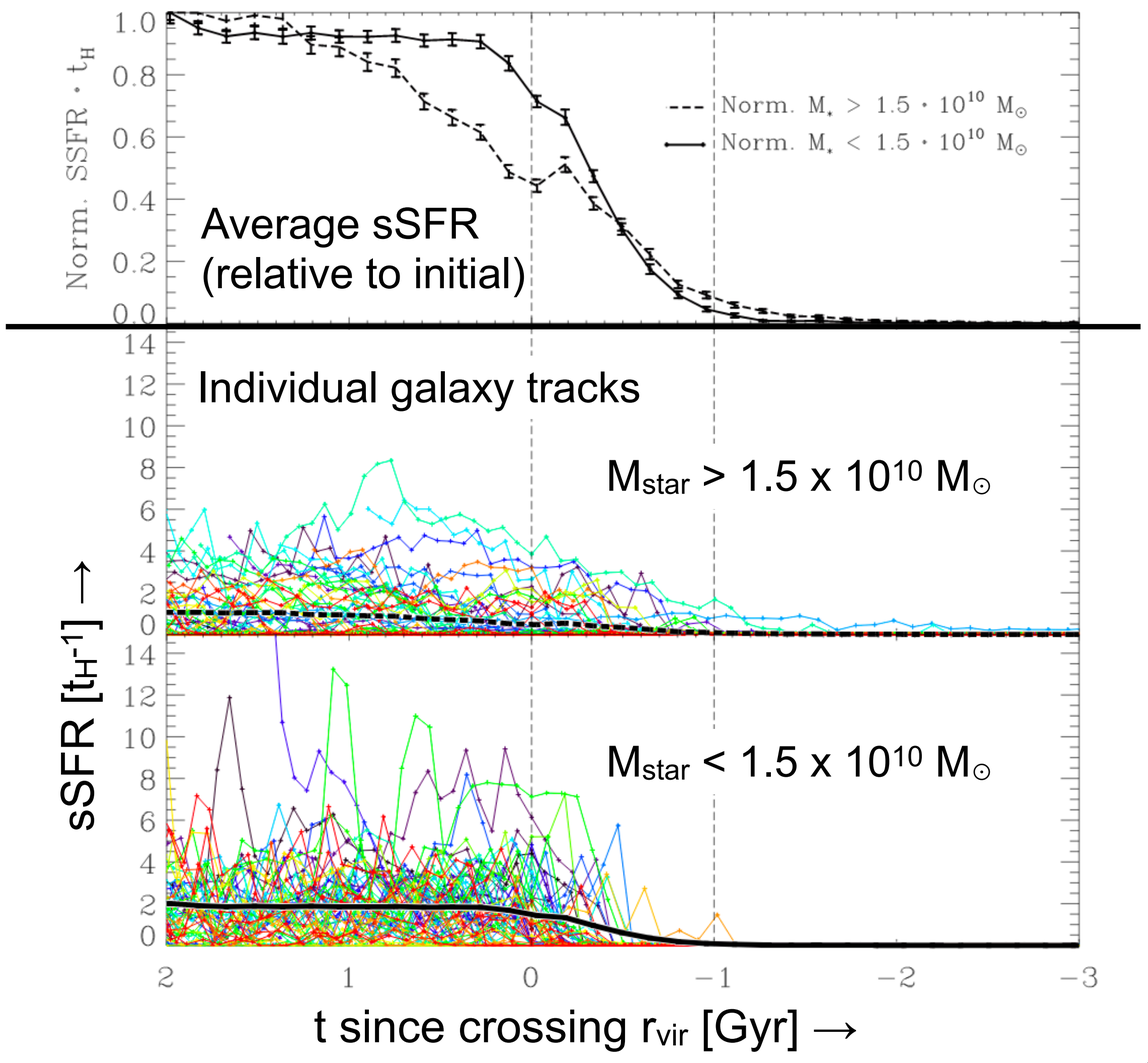
Also (e.g.): Cunnama+14, Sales+15, Marasco+16, YMB+17

Atomic hydrogen content



Stevens+18 (IllustrisTNG)

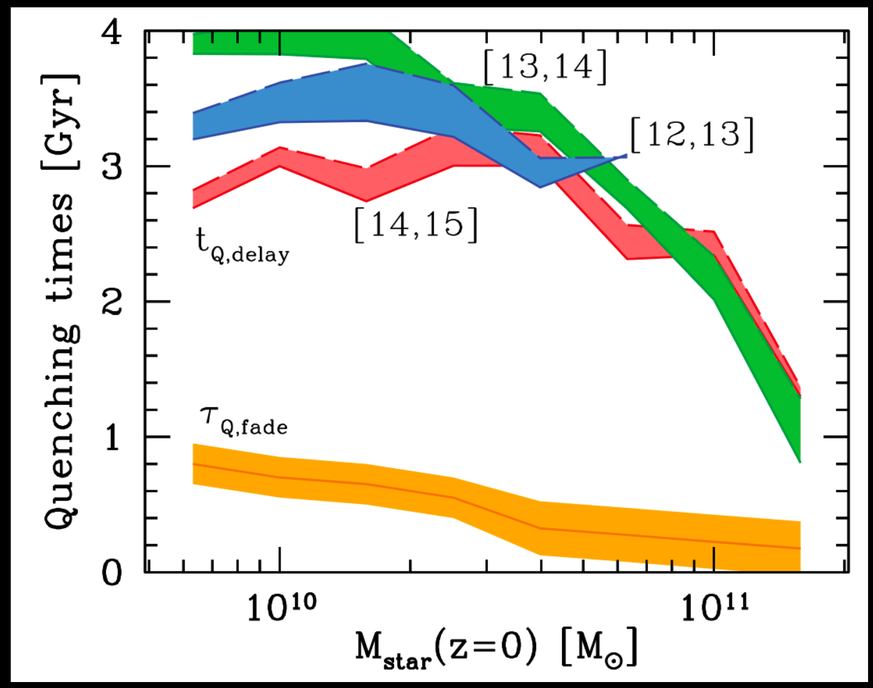
QUENCHING TIMESCALES IN COSMOLOGICAL SIMULATIONS [SKIPPED IN TALK]



Adapted from Lotz+18
(Magneticum Pathfinder)

Rapid quenching after ***final*** infall (≲ 1 Gyr)

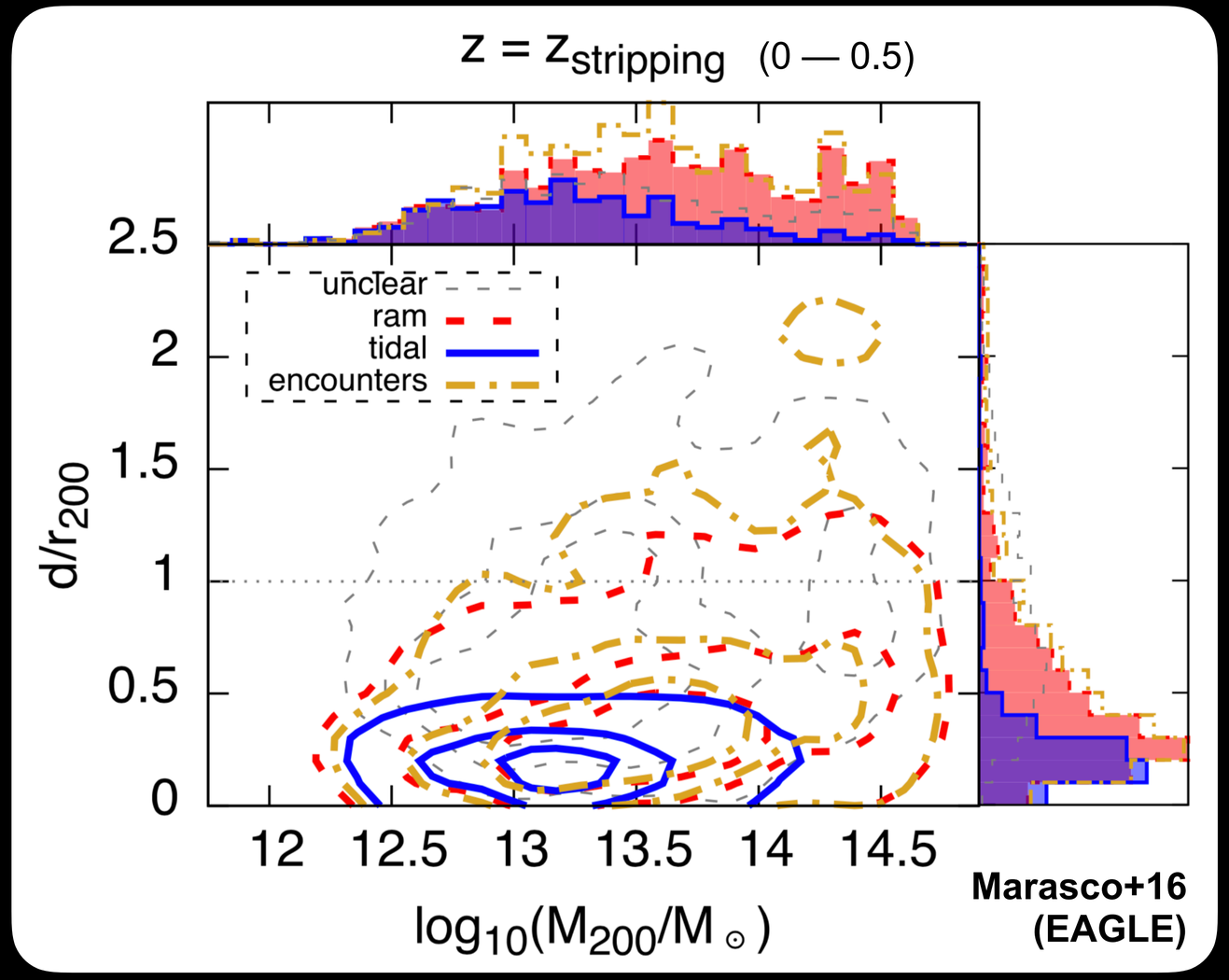
Consistent with observations
(N.B.: $<t_{pre\text{-}proc}> \approx 2.5$ Gyr)

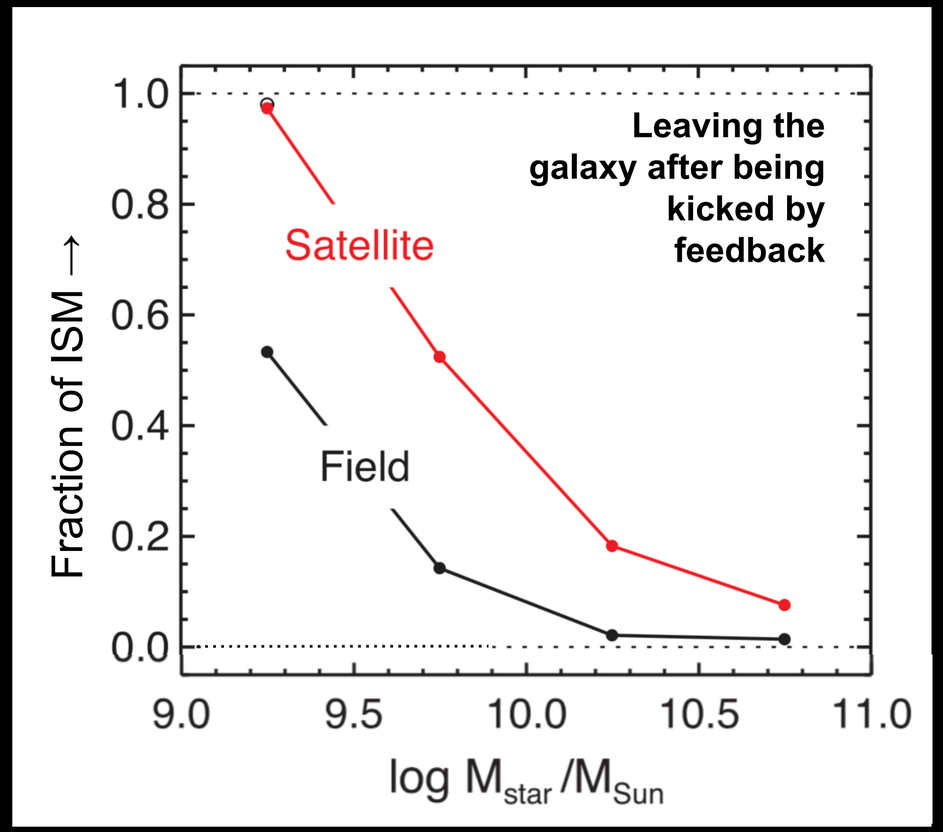


Wetzel+13 (Observations + N-body)

Also (e.g.): Feldmann+11, Sales+15, YMB+15, Mistani+16, Pallero+18, Correa+18, Simpson+18, Wright+18, Joshi+19

EXPLANATION: ENCOUNTERS AND STRIPPING — ASSISTED BY FEEDBACK



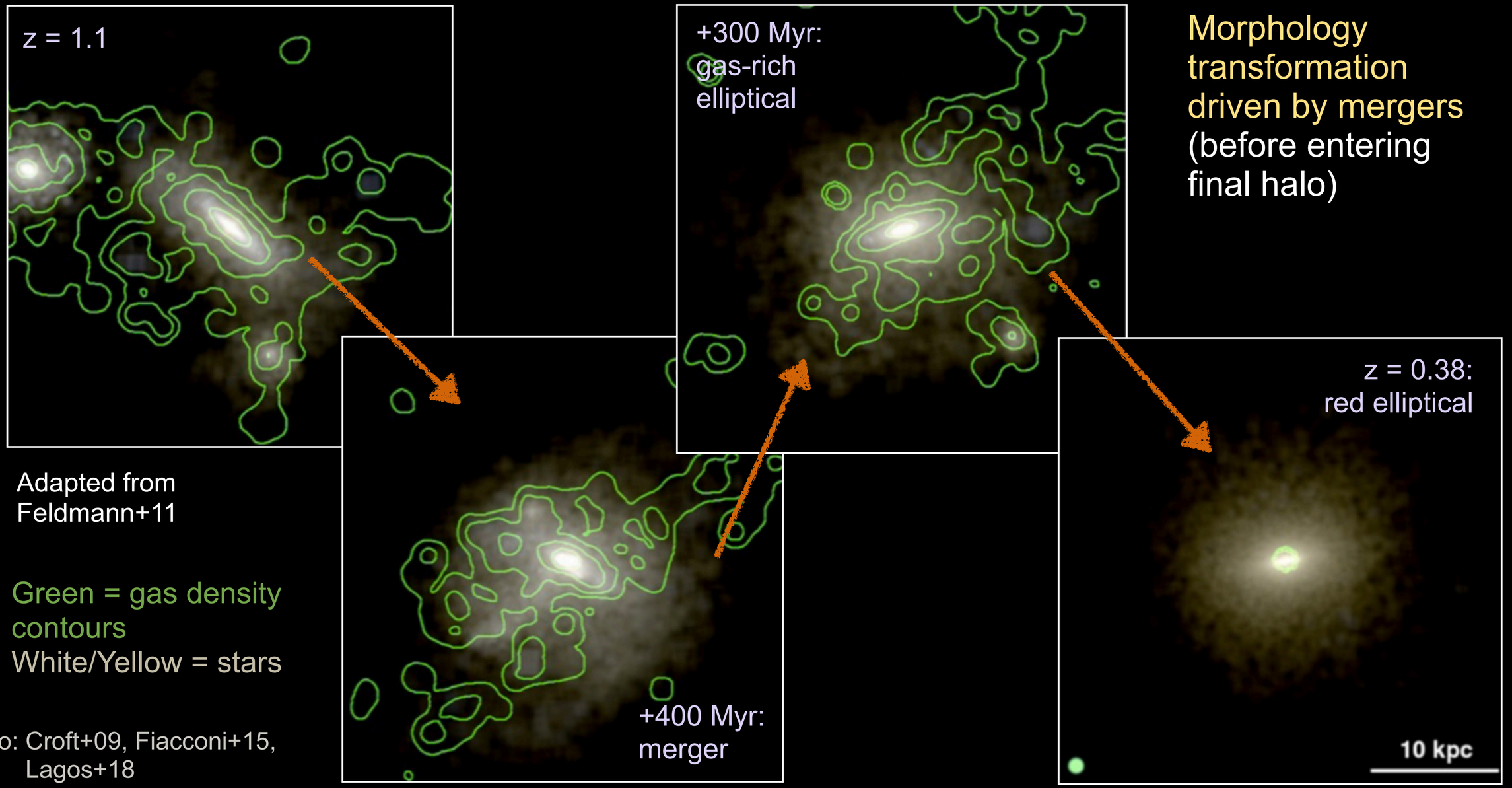


Adapted from YMB & McCarthy 2015 (GIMIC)

Also (e.g.): Cen+14, Cunnama+14, YMB & McCarthy 15, Rafieferantsoa+15, Brown+17, Simpson+18, Stevens+18, Hausammann+18

Gas removal dominated by (assisted) ram pressure stripping and satellite encounters

What causes morphology change in satellites?



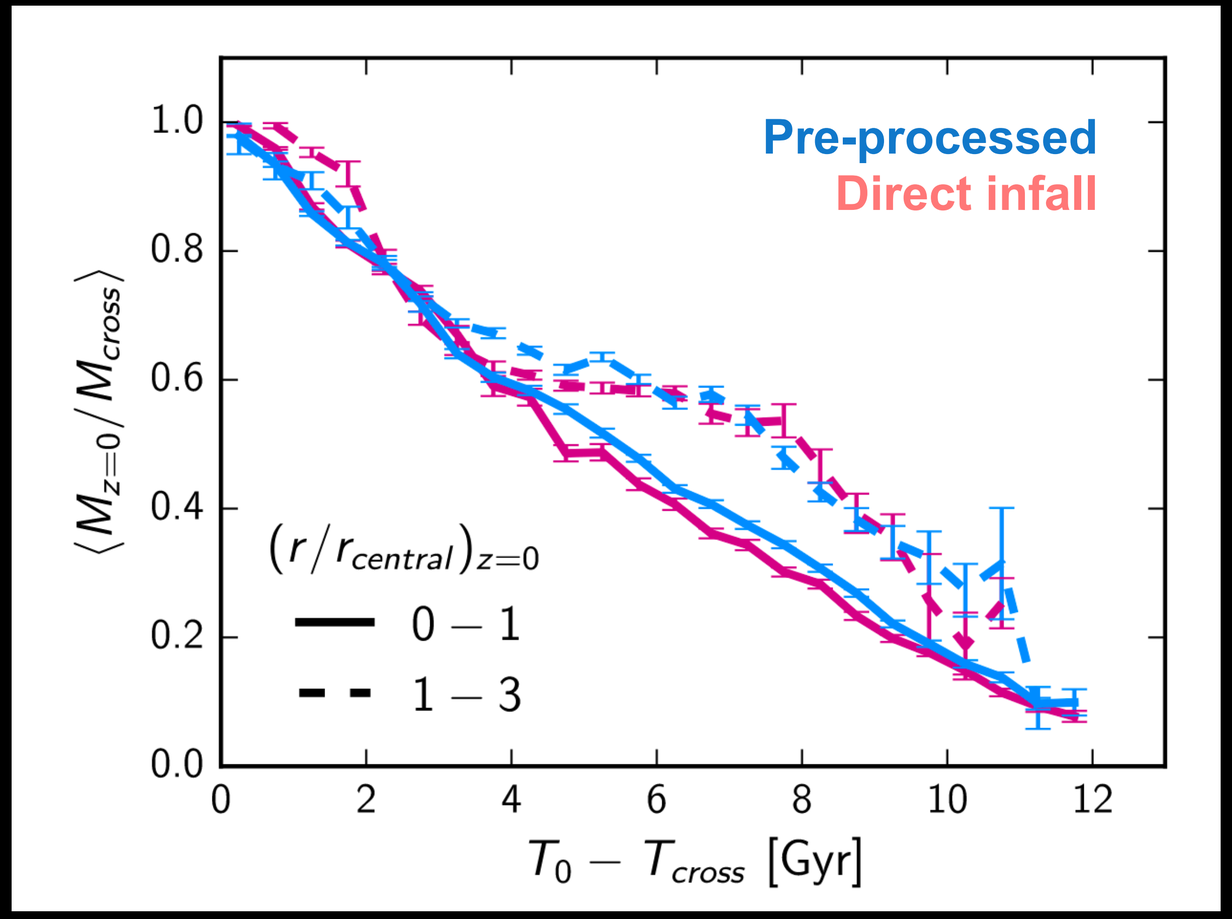
Morphology transformation driven by mergers (before entering final halo)

Adapted from Feldmann+11

Green = gas density contours
White/Yellow = stars

Also: Croft+09, Fiacconi+15, Lagos+18

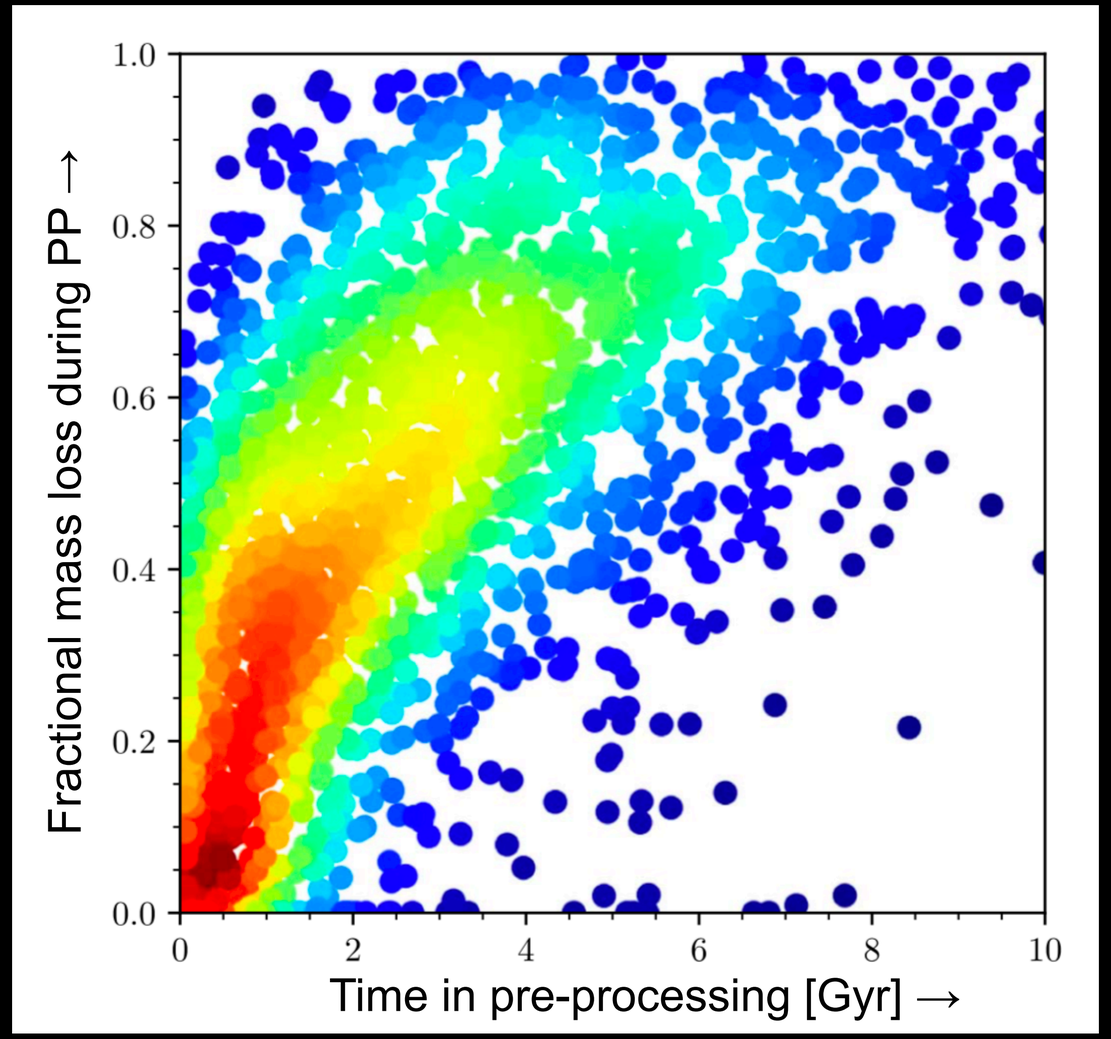
STRIPPING OF DARK MATTER



Adapted from Joshi+17
(N-body only)

Significant mass loss,
depending on infall time

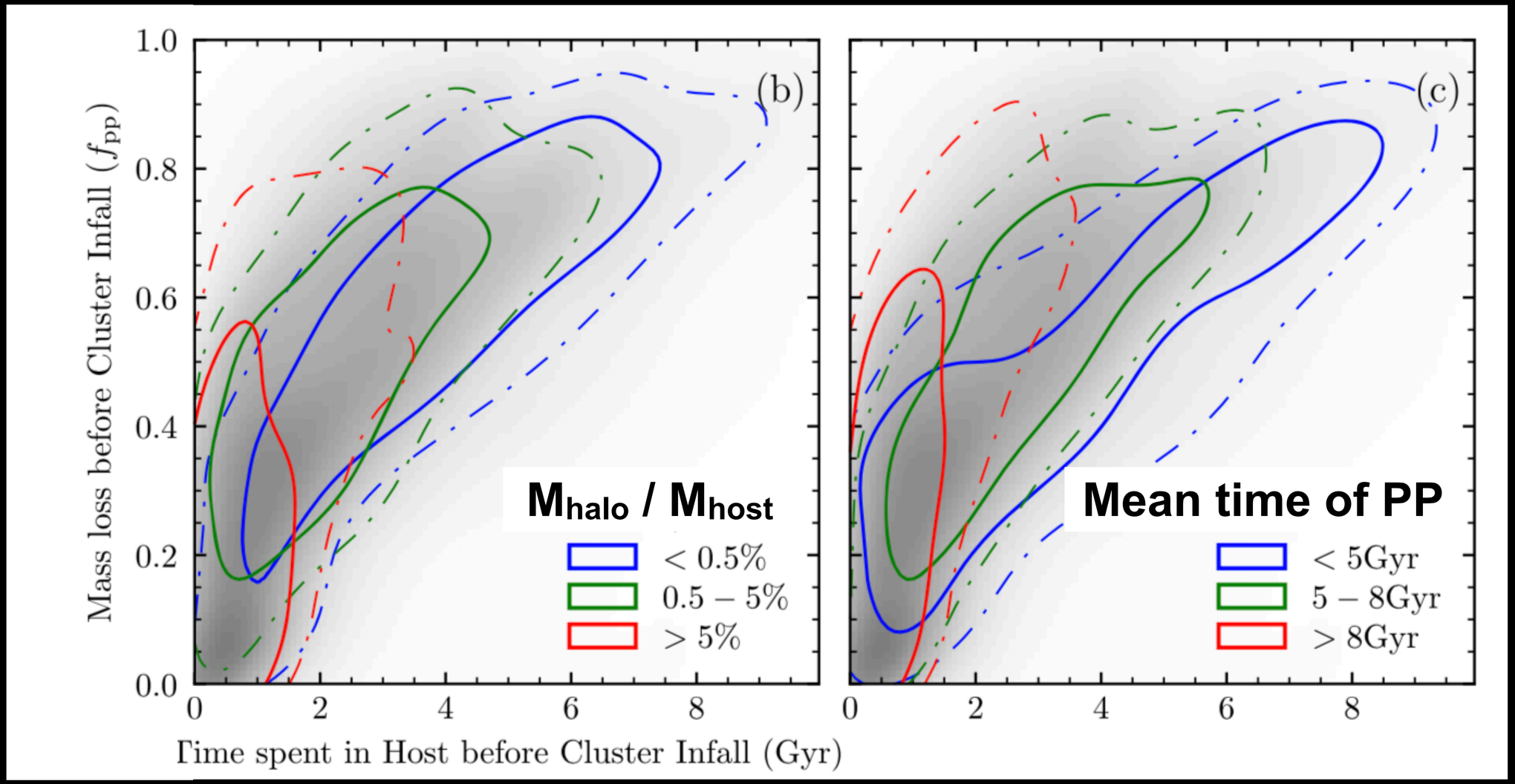
Also (e.g.): Gao+04, 12, Giocoli+10, Xie & Gao 15,
YMB+17, Rhee+17, v,d. Bosch 17



Similar effect already in
pre-processing

Han+18
(YZiCS)

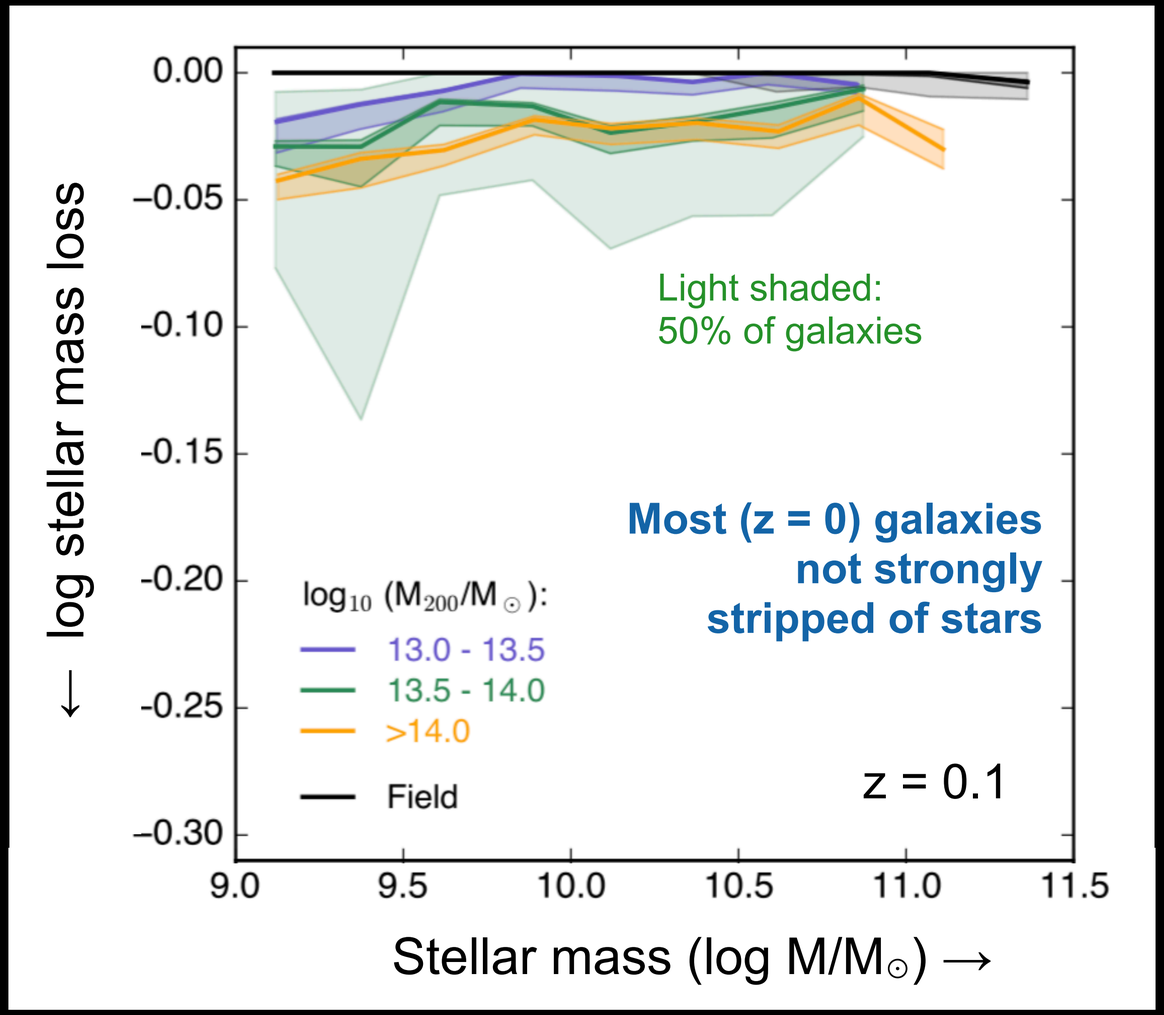
STRIPPING OF DARK MATTER



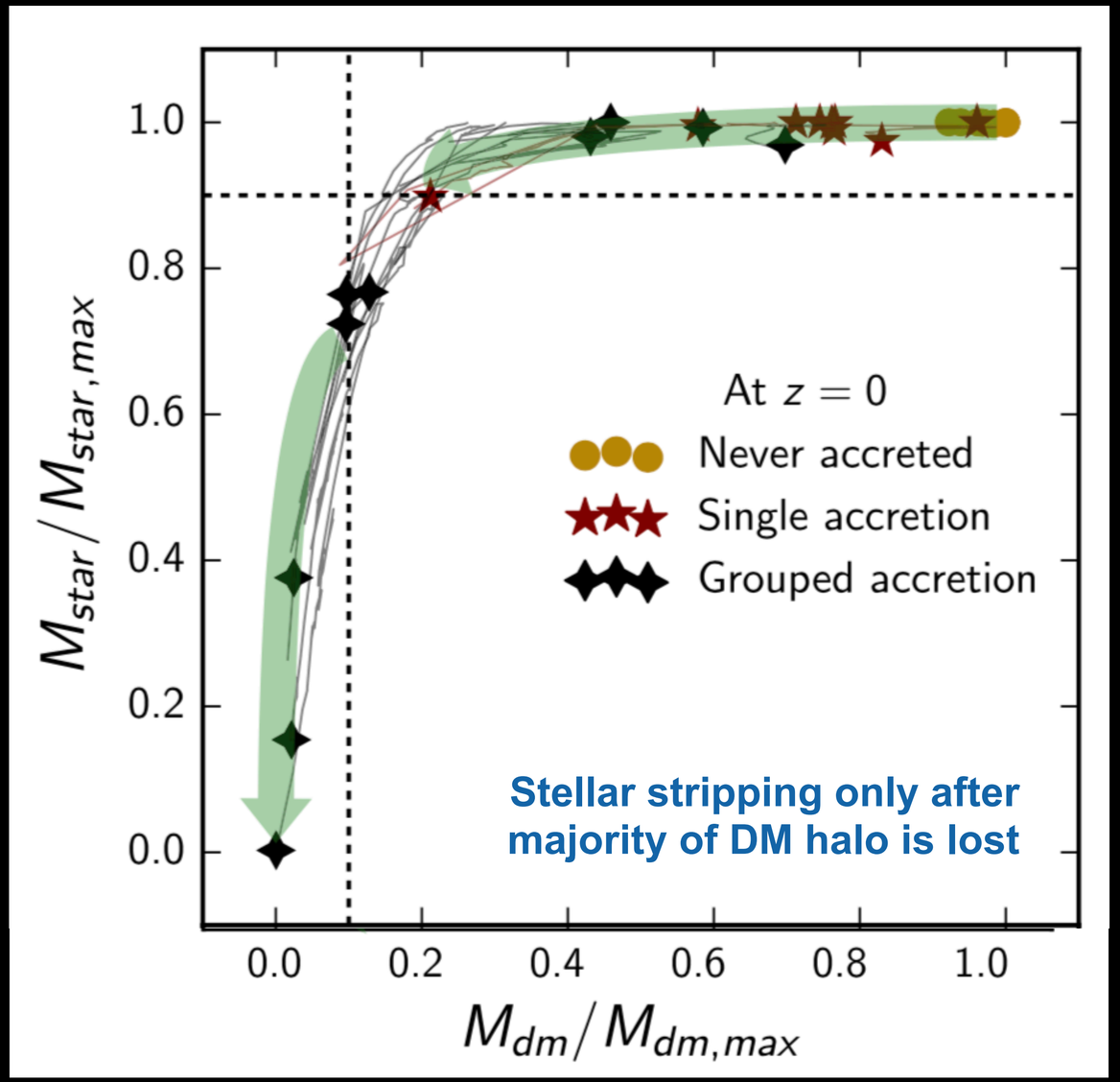
PP mass loss is stronger in lower-mass hosts and at earlier times

Adapted from Han+18 (YZiCS)

STRIPPING OF STARS



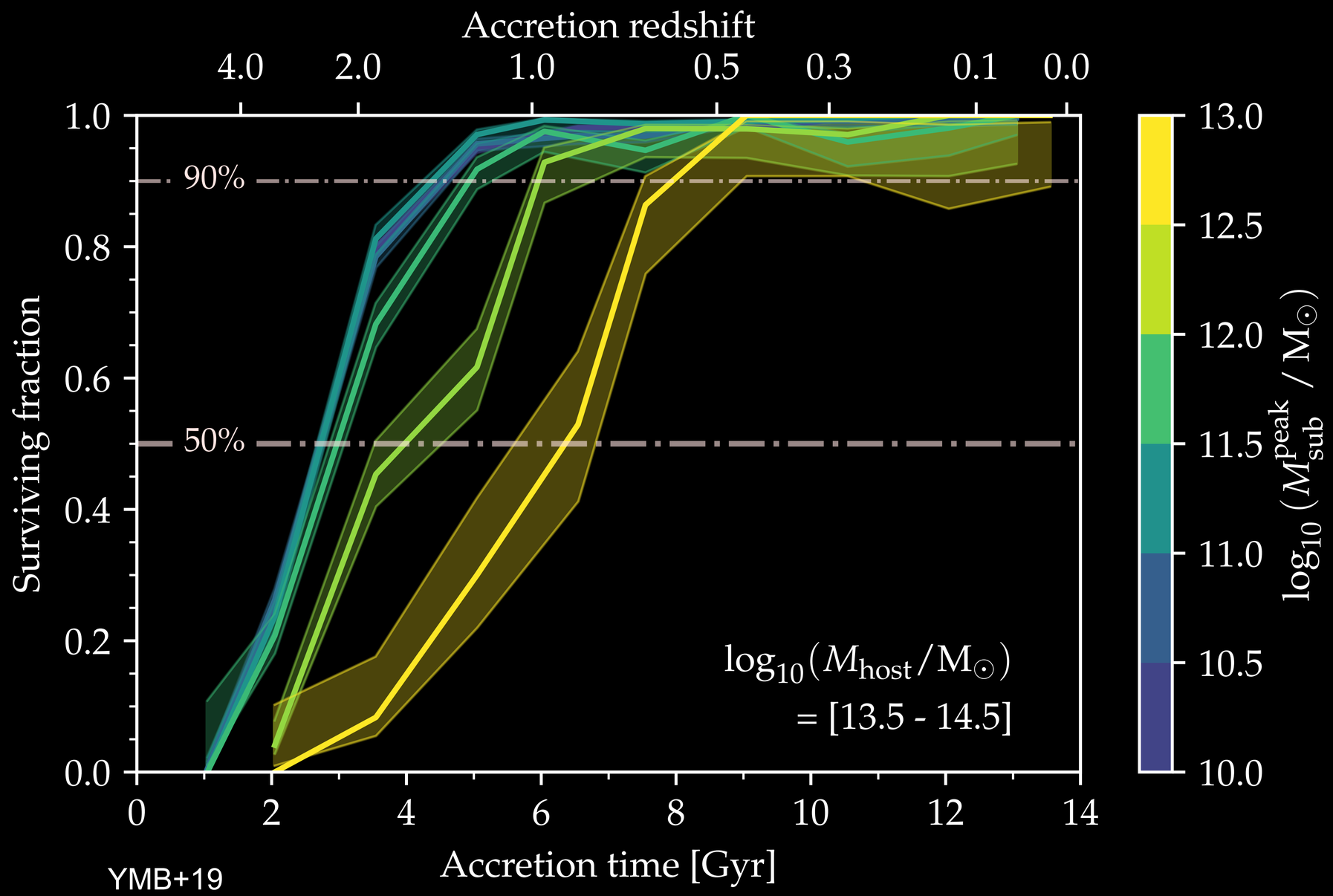
YMB+17
(EAGLE)



Joshi+19
(Group zoom)

Also (e.g.): Bekki+03, Peñarrubia+08, Pfeffer & Baumgardt 13, Han+15, Barber+16, Smith+16, Mistani+16, v. Son+19

Complete Disruption of satellites



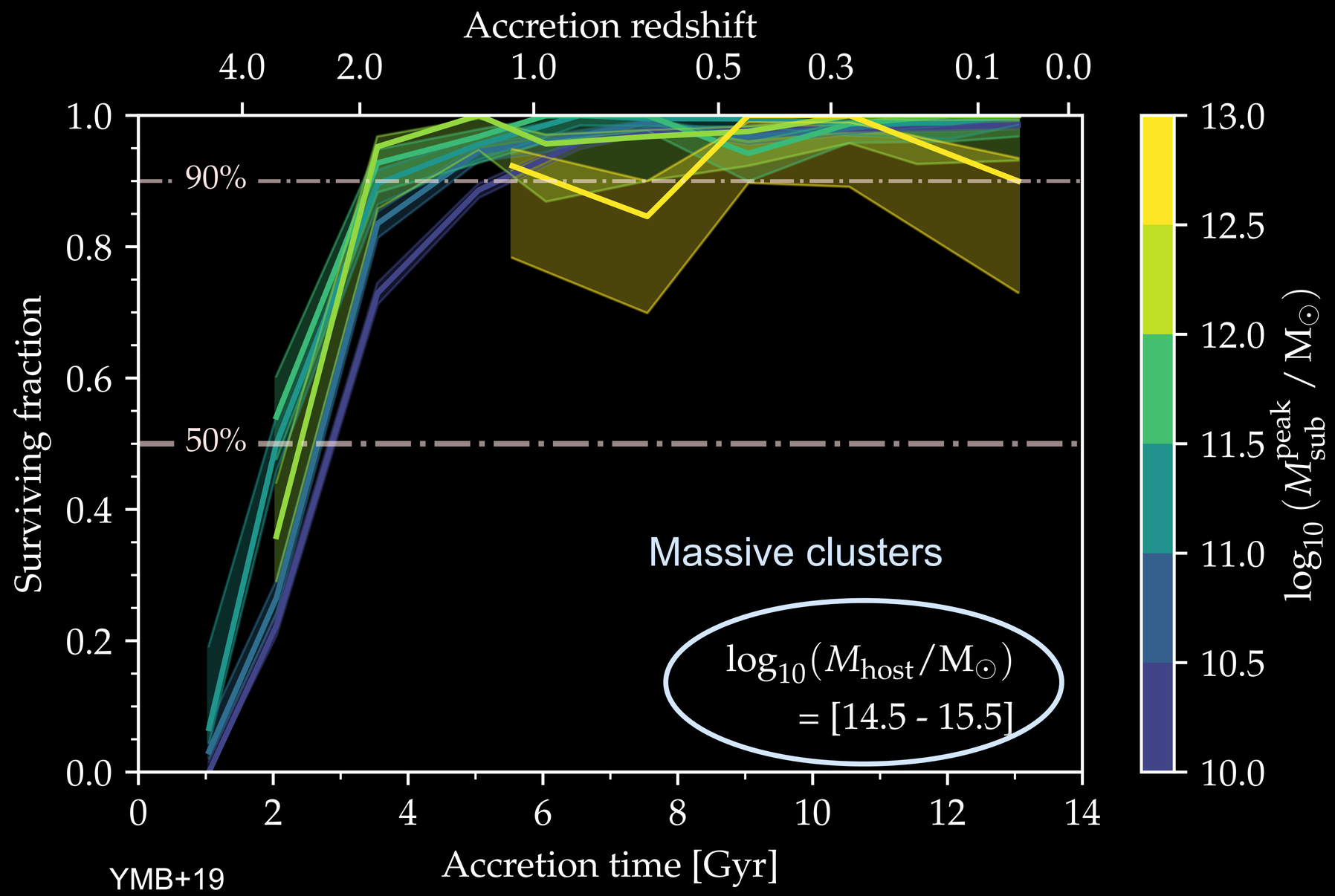
Direct accretion only (not pre-processed)

Strong, non-linear dependence on accretion redshift

"Transition redshift" depends on galaxy mass

Complete Disruption of satellites

[skipped in talk]



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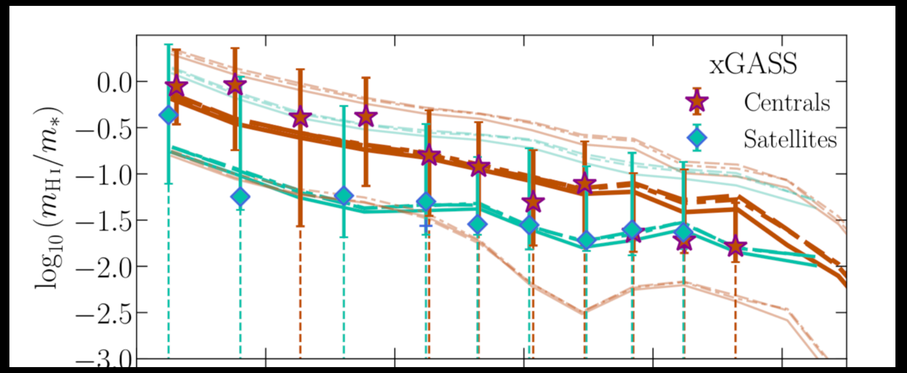
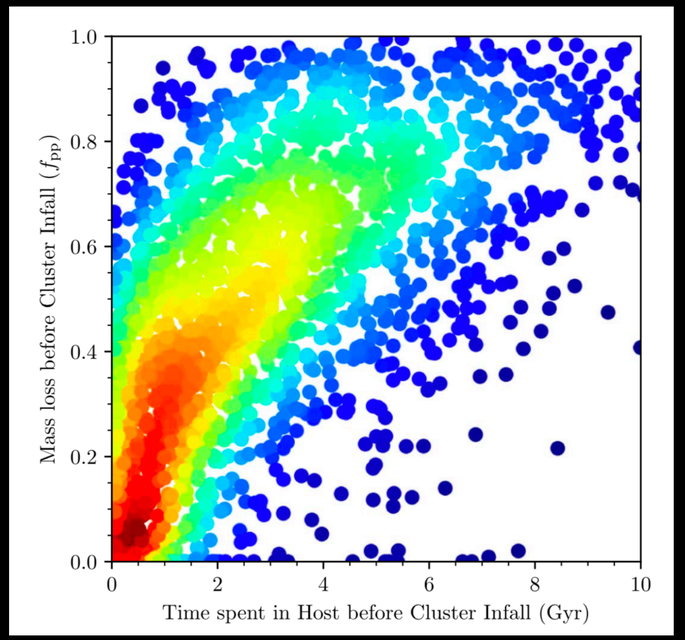
Strong, non-linear dependence on accretion redshift

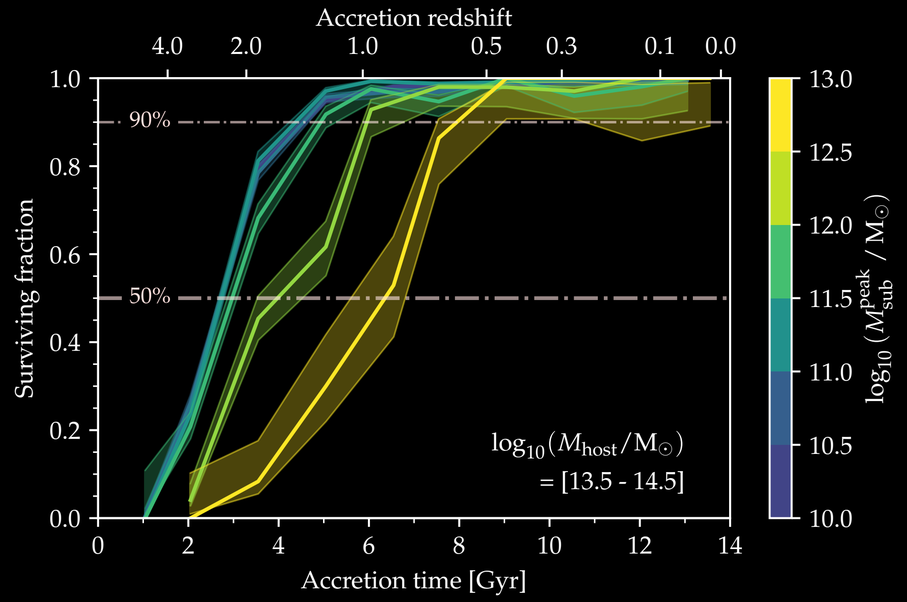
"Transition redshift" depends on galaxy (and host) mass

SUMMARY



1- Modern hydrodynamical simulations reproduce many environmental effects well, with room for more tests





3 - Prediction: total disruption of satellites in clusters only when they were accreted early

2 - Simulations provide insight into physical processes: assisted ram pressure stripping (gas) tidal stripping during pre-processing (DM)