The Three Hundred

A short overview

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In collaboration with the core team and players.

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[1] https://weiguangcui.github.io

The Three Hundred: Basic information

- The most massive ($M_{vir} > 8 \times 10^{14}\ h^{-1}\,\mathrm{M}_{\odot}$) 324 clusters are selected from the MultiDark simulation(MDPL2)[2].
- 324 zoomed-in ICs are generated by cutting a spherical region with a radius of $15\ h^{-1}\ \mathrm{Mpc}$ from the cluster center.

Table: Parameters of the Three Hundred simulations

Parameter	Value	Description
Ω_M	0.307	Total Matter density parameter
Ω_B	0.048	Baryon density parameter
Ω_Λ	0.693	Cosmological Constant density parameter
h	0.678	Hubble constant in units of 100 km/s/Mpc
σ_8	0.823	Normalization of Power spectrum
n_s	0.96	Power index
z_{init}	120	Initial redshift of the simulations
ϵ_{phys}	6.5	Plummer equivalent softening in $h^{-1}\ \mathrm{kpc}$
Particle mass	2.36 (12.7)	gas (DM) in $[10^8\ h^{-1}\,\mathrm{M}_{\odot}]$

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[2] https://www.cosmosim.org

The Three Hundred: theoretical models

hydrodynamical simulations with baryonic models:

GADGET-MUSIC: classic SPH method. Radiative cooling, star formation with both thermal and kinetic Supernove (SN) feedback.
GADGET-X: modern SPH with the Wendland C4 kernel. Gas cooling with metal contributions, star formation with chemical enrichment, SN feedback with AGB phase, and AGN feedback.
GIZMO-MUFASA/SIMBA: see more information in Mika/Romeel's talks.
GADGET-PESPH: running.

SAMs galaxies from MultiDark-Galaxies:

GALACTICUS
SAG see more information in Sofia's talk.
SAGE. see more information in Adam's talk.
See Knebe et al. 2018 (MNRAS, 474, 5206), for details.
Notes: only galaxies/clusters from the same regions as the hydrodynamical simulations are selected.

The Three Hundred: what do we have for playing?

Simulations	snaps	AHF	Rocks.	VELOCIr.	dynamic	CCD	SZ	XRAYS	lensing
MDPL2	324 regions 4 outputs	done	done	?	z=0	X	X	X	?
GadgetX	324 regions 128 outputs	done	?	?	4 snaps	few	z=0	z=0	?
MUSIC	324 regions 17/128 outputs	done	?	?	4 snaps	few	z=0	z=0	?
MUFASA	few regions 128 outputs	done	?	?	?	?	?	?	?
Simba	few regions 128 outputs	done	?	?	?	?	?	?	?
PESPH	? ?	?	?	?	?	?	?	?	?
SAMs									
Galacticus	324 regions z=0 outputs	X	X	X	X	X	X	X	X
SAG	324 regions z=0 outputs	X	X	X	X	X	X	X	X
SAGE	324 regions z=0 outputs	X	X	X	X	X	X	X	X

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The Three Hundred: the catalogues

Halos and subhalos in hydrodynamical simulations are identified with AHF (Ref: Knollmann & Knebe 2009).

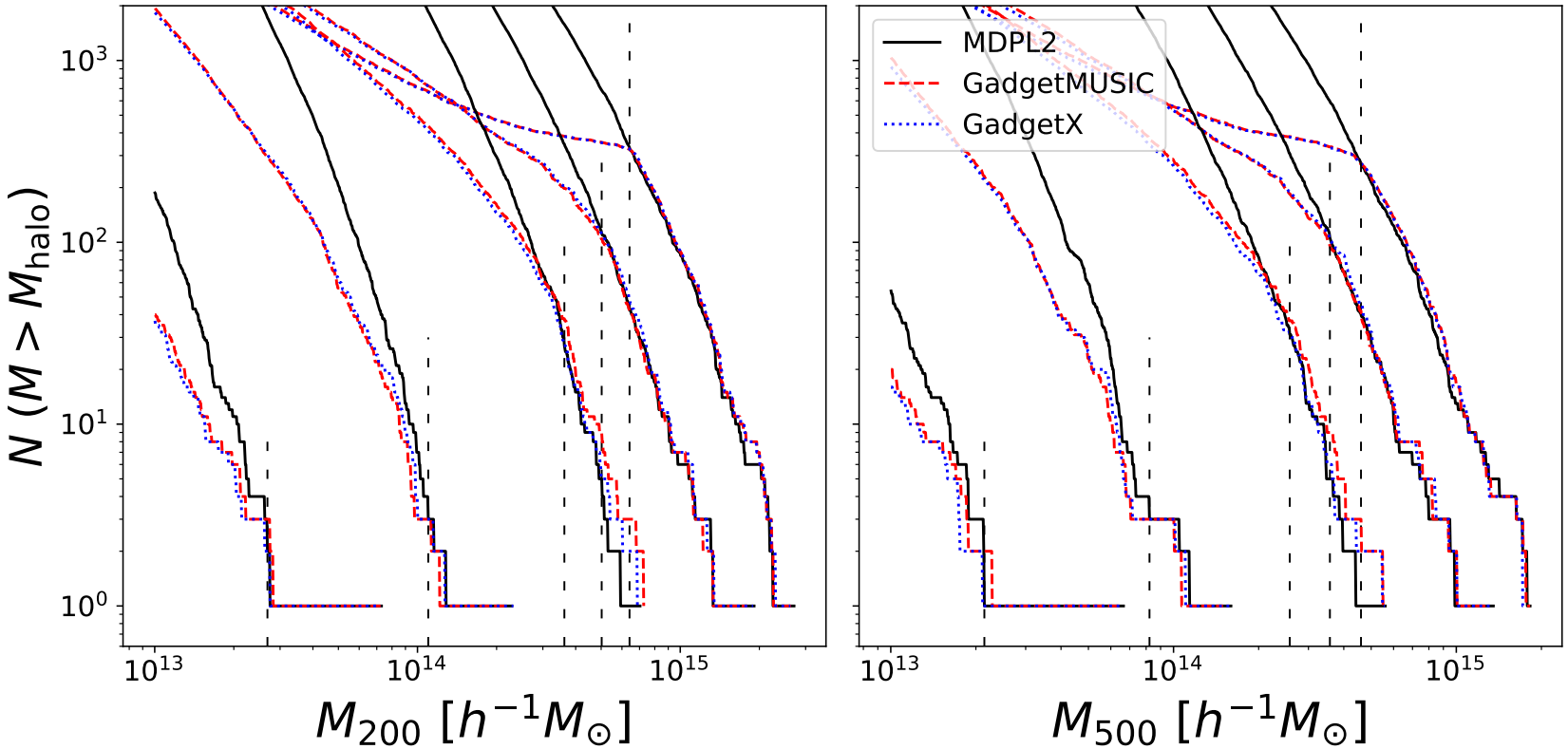

Figure: Cumulative halo mass functions.

The Three Hundred: the catalogues

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Table: The infamous complete sample of the Three Hundred cluster catalogues at different redshifts.

redshift	M_{200c} $[10^{14}\ h^{-1}\ \mathrm{M}_\odot]$	N_{200c} MUSIC/X	M_{500c} $[10^{14}\ h^{-1}\ \mathrm{M}_\odot]$	N_{500c} MUSIC/X
0.0	6.42	324 / 324	4.60	270 / 270
0.5	5.02	104 / 110	3.57	94 / 103
1.0	3.62	38 / 27	2.57	37 / 31
2.3	1.10	3 / 3	0.82	3 / 3
4.0	0.27	3 / 2	0.21	2 / 1

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General Properties: Baryon effects on halo mass

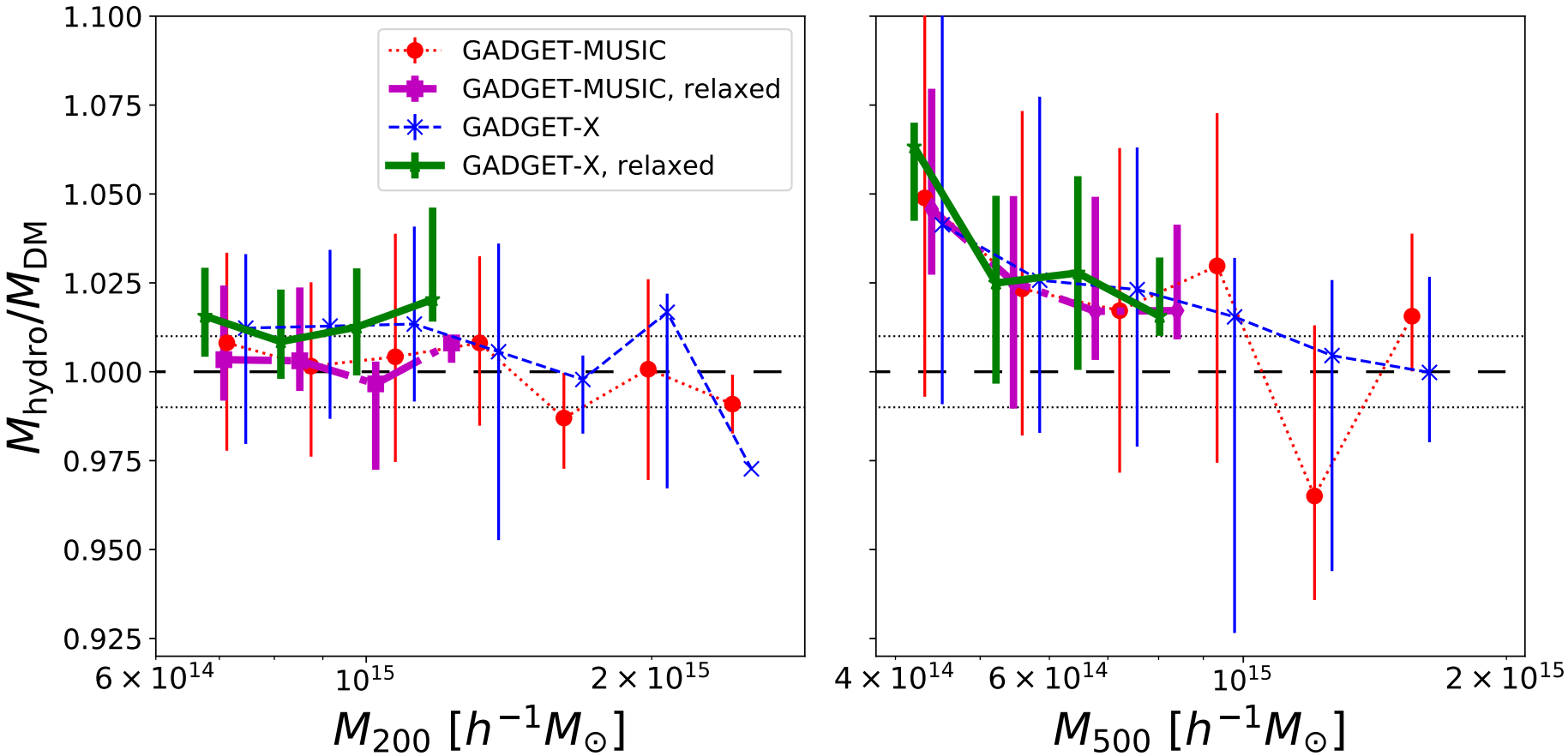

Figure: halo mass difference respected to the DM run.

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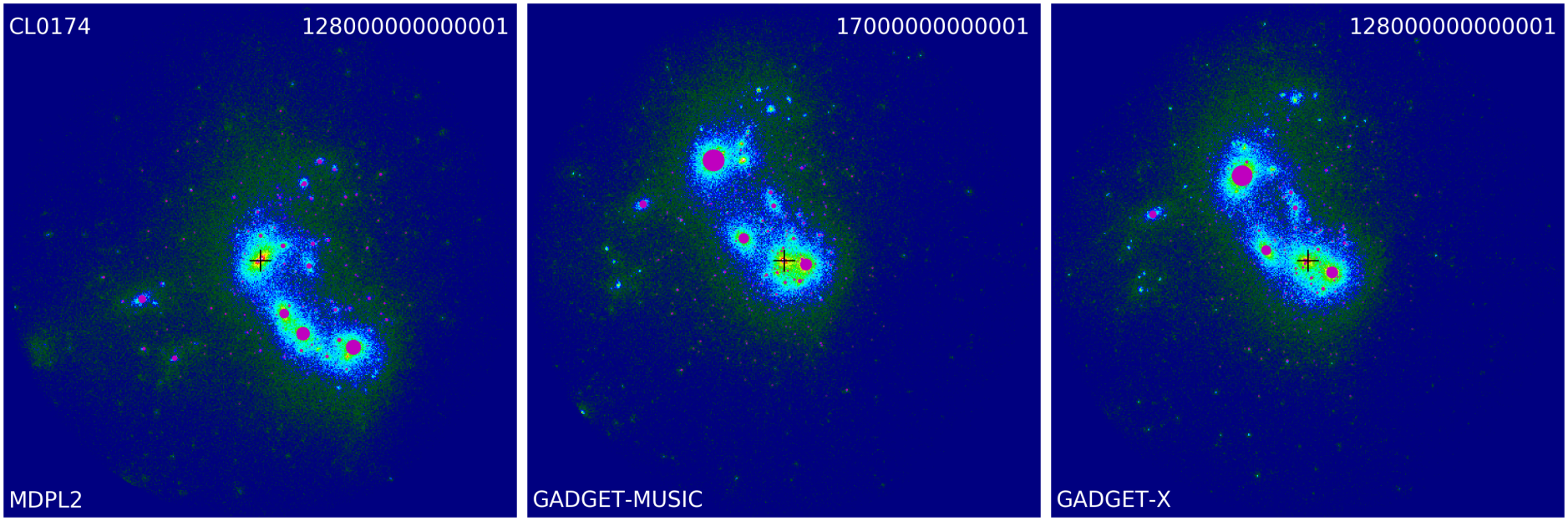
General Properties: Baryon effects on halo mass

The mismatching problem.



Plots for the complete sample are available.

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General Properties: the dynamical state

We applied 3 criteria to classify the cluster's dynamical state to relaxed and un-relaxed: the virial ratio $\eta = (2T - E_s)/|W|$ with $0.85 < \eta < 1.15$, center-of-mass offset $\Delta_r = |R_{cm} - R_c|/R_{200c} < 0.04$ and subhalo mass fraction $f_s = \sum M_{sub}/M_{200c} < 0.1$.

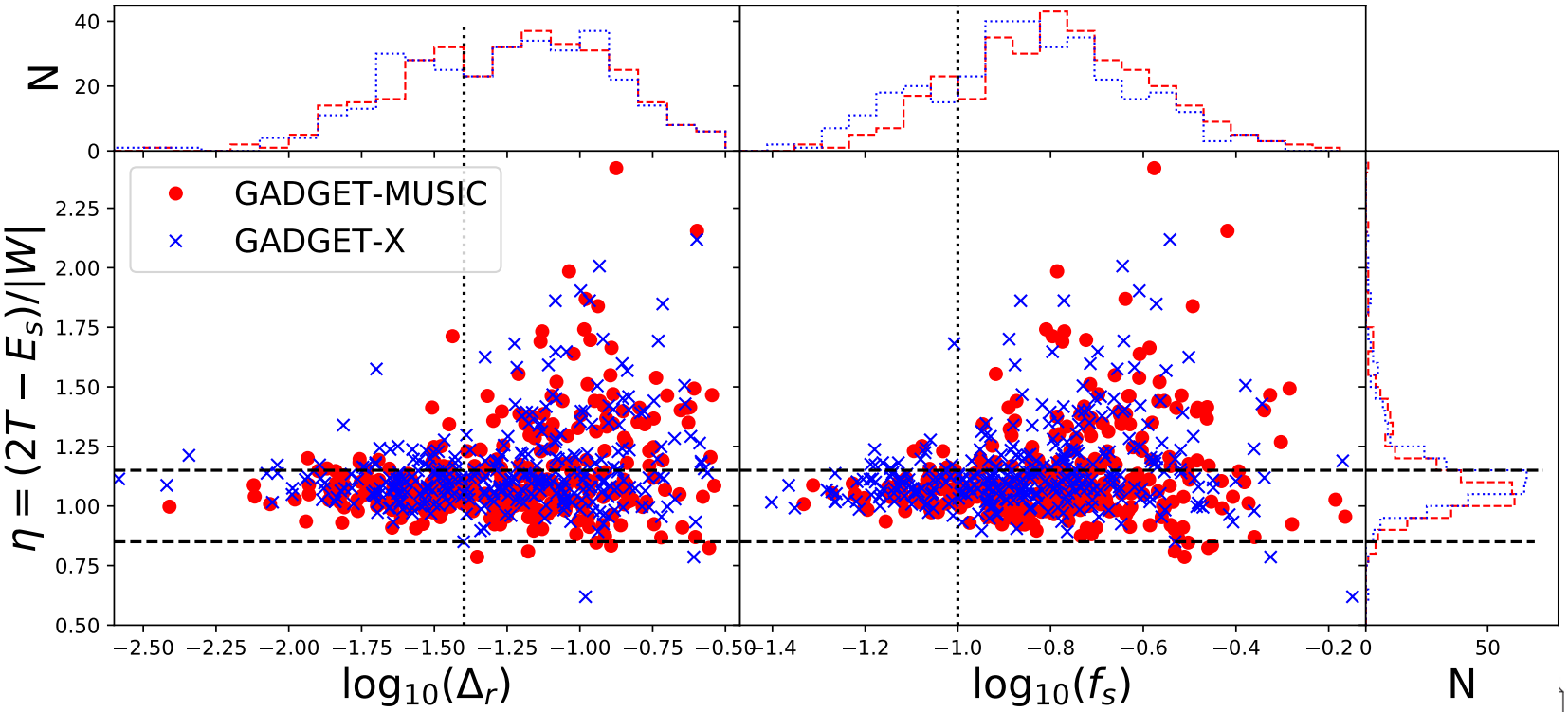

Figure: The relations between the three parameters.

General Properties: the dynamical state

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Table: The fractions of relaxed clusters with different combinations of criteria.

M_{200c} $10^{14}\ h^{-1}\ \mathrm{M}_\odot$	η, Δ_r & f_s MUSIC/X	Δ_r & f_s MUSIC/X	f_s MUSIC/X
$0.10 - 0.50$	0.44 / 0.36	0.56 / 0.48	0.70 / 0.65
$0.50 - 1.00$	0.36 / 0.34	0.45 / 0.46	0.56 / 0.57
$1.00 - 6.41$	0.27 / 0.29	0.30 / 0.35	0.43 / 0.48
$6.41 - 10$	0.18 / 0.21	0.20 / 0.24	0.21 / 0.26
> 10	0.06 / 0.08	0.07 / 0.13	0.07 / 0.14

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General Properties: the CC fractions

Methods: Rossetti et al. 2001. Further, we verified that using the central entropy gives the same CC fraction.

Table: The Cool Core cluster fraction in the complete sample: $f_{CC} = \frac{N_{CC}}{N_{total}}$, the CC fraction in dynamically relaxed clusters $f_{CC/dr} = \frac{N_{CC,relaxed}}{N_{relaxed}}$ and the relaxation fraction in CC $f_{dr/CC} = \frac{N_{CC,relaxed}}{N_{CC}}$.

Simulation	f_{CC}	$f_{CC/dr}$	$f_{dr/CC}$
MUSIC	0.09	0.04	0.07
X	0.26	0.33	0.21

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General Properties: the baryon fractions

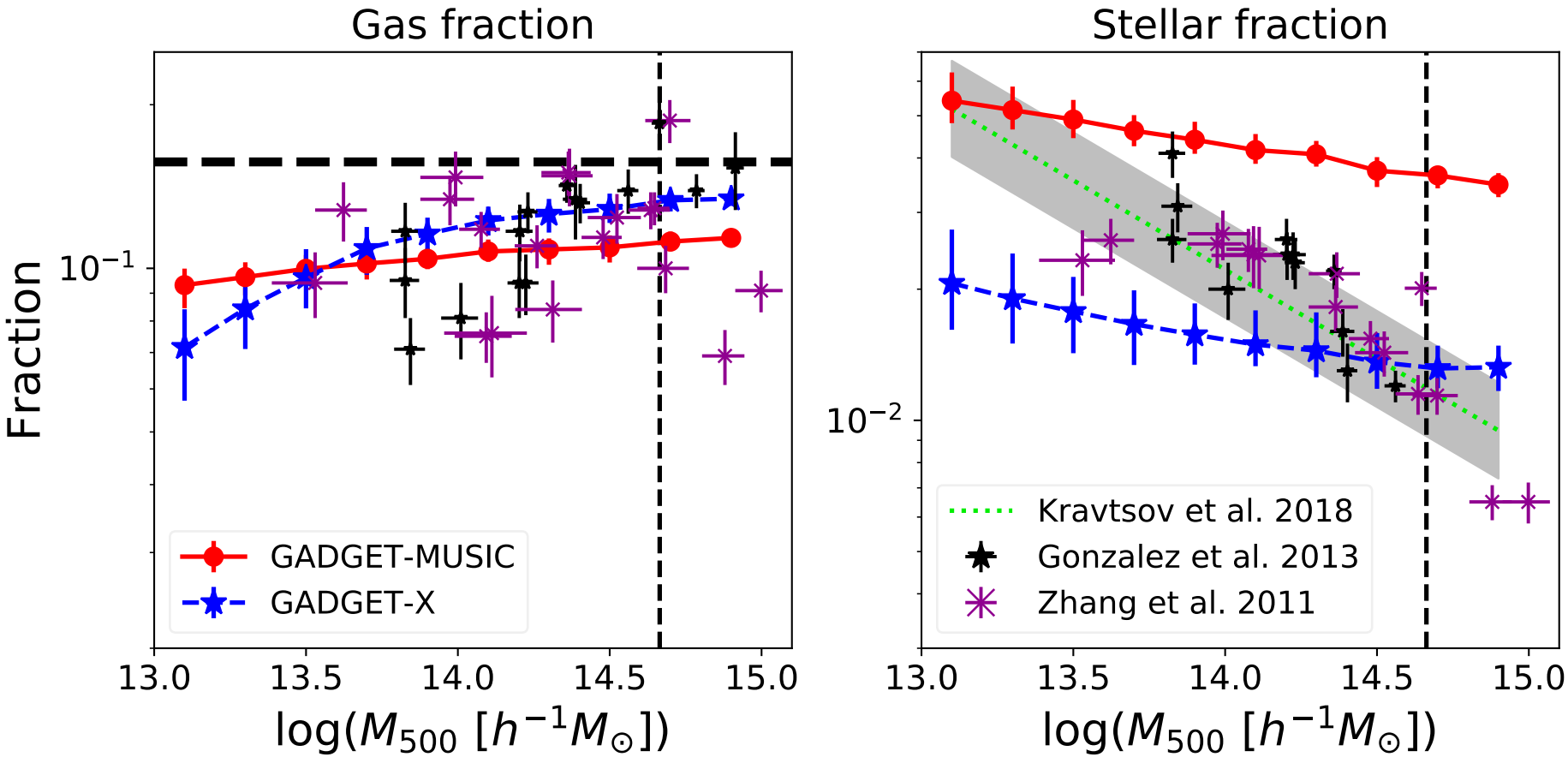

Figure: The baryon fractions compared with observations.

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General Properties: the baryon fractions

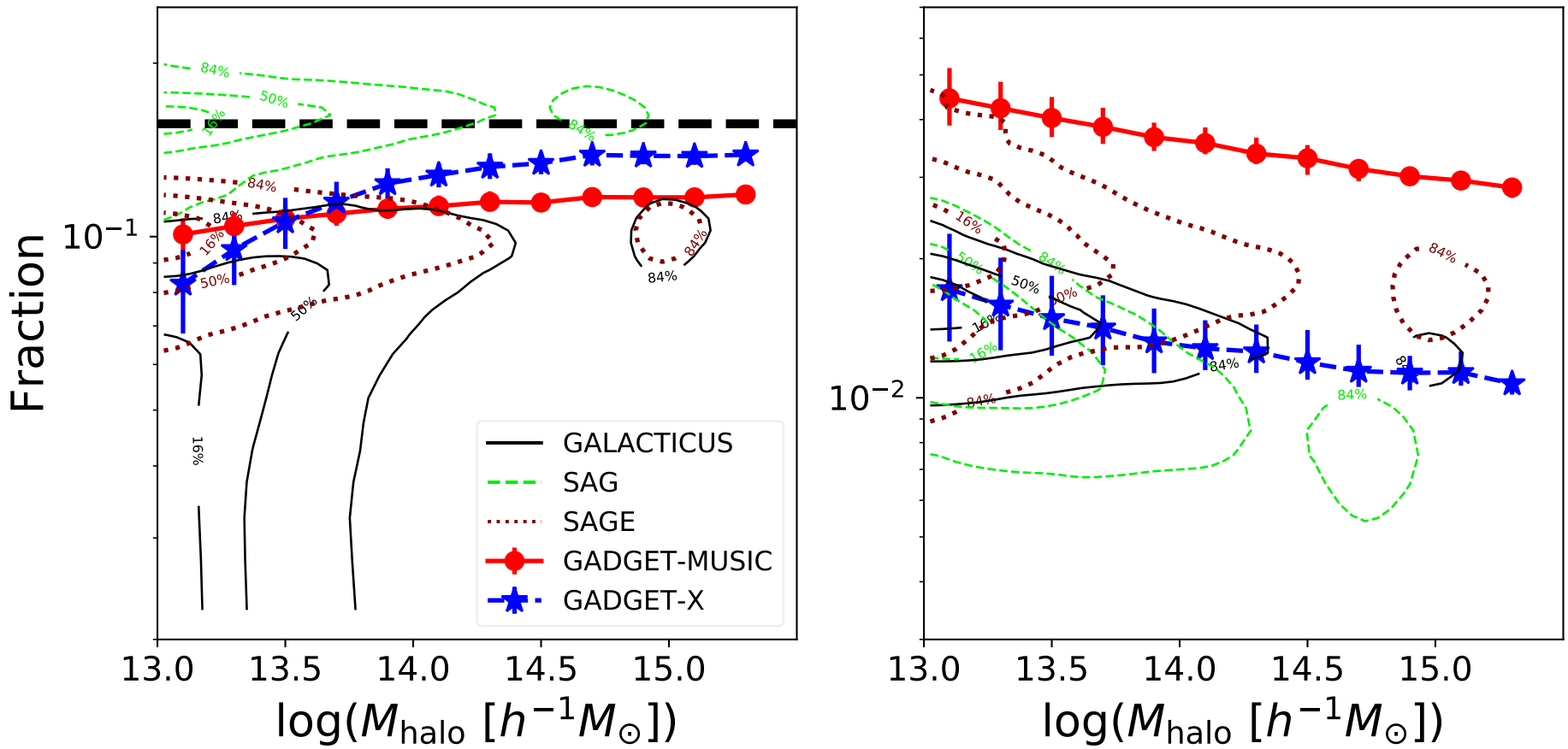
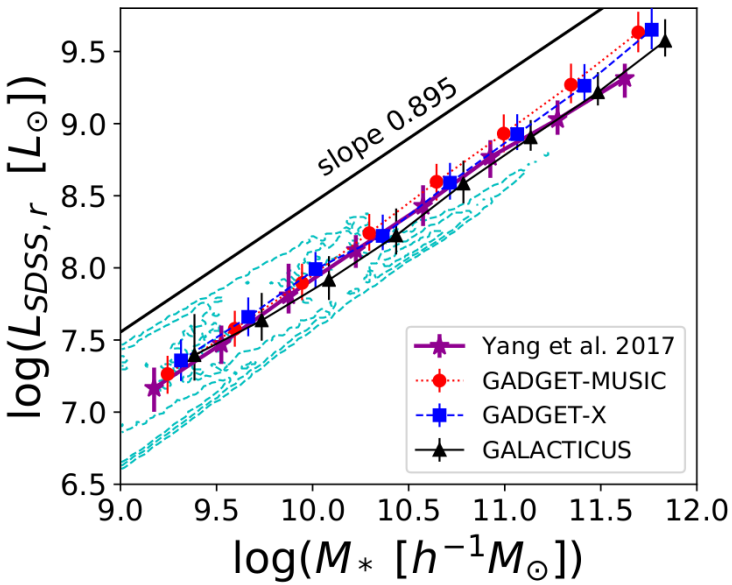
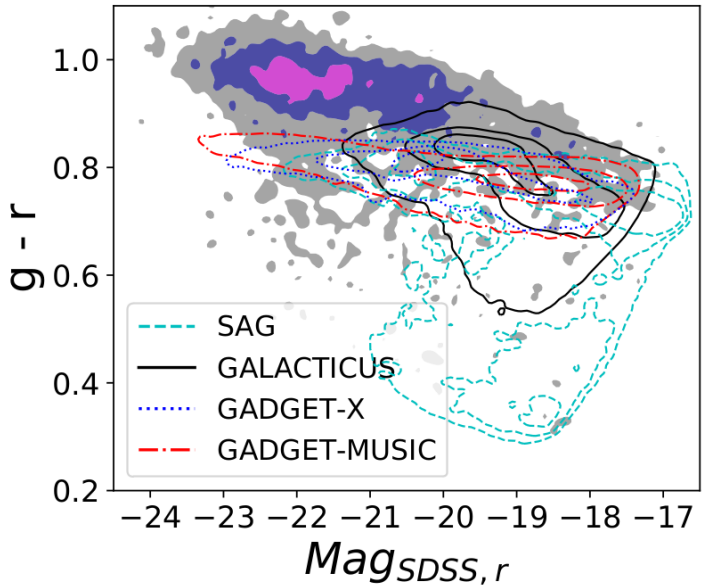


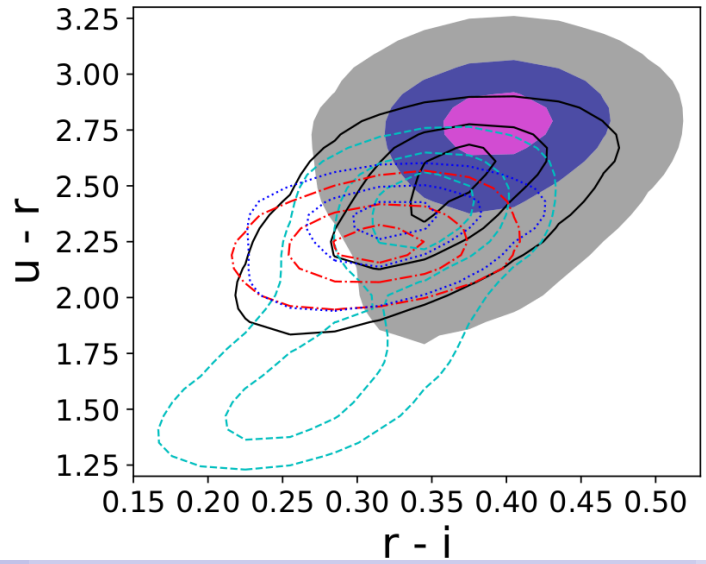
Figure: The baryon fractions in halo compared with SAMs.

Optical relations

The complete sample is used here.

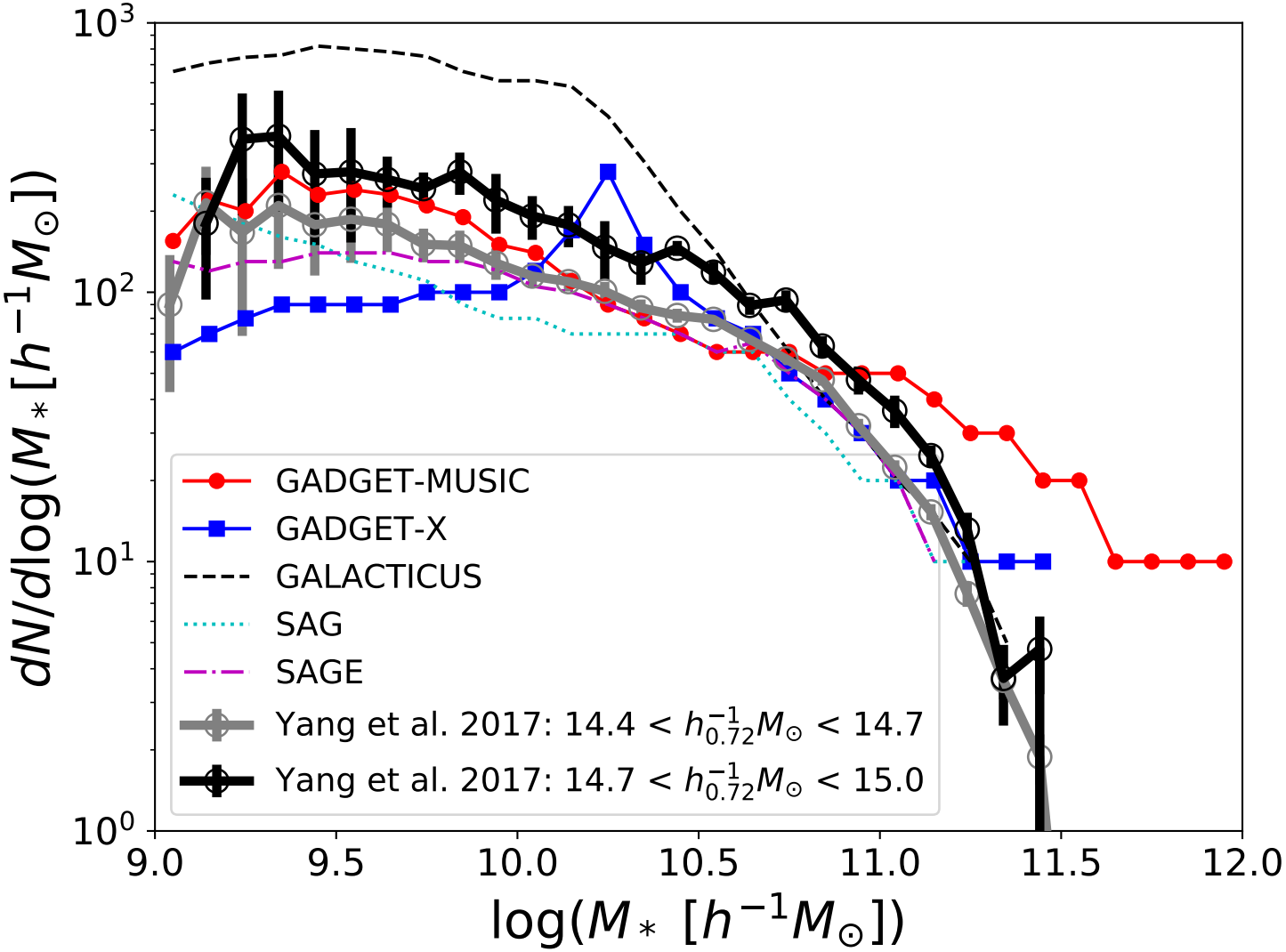






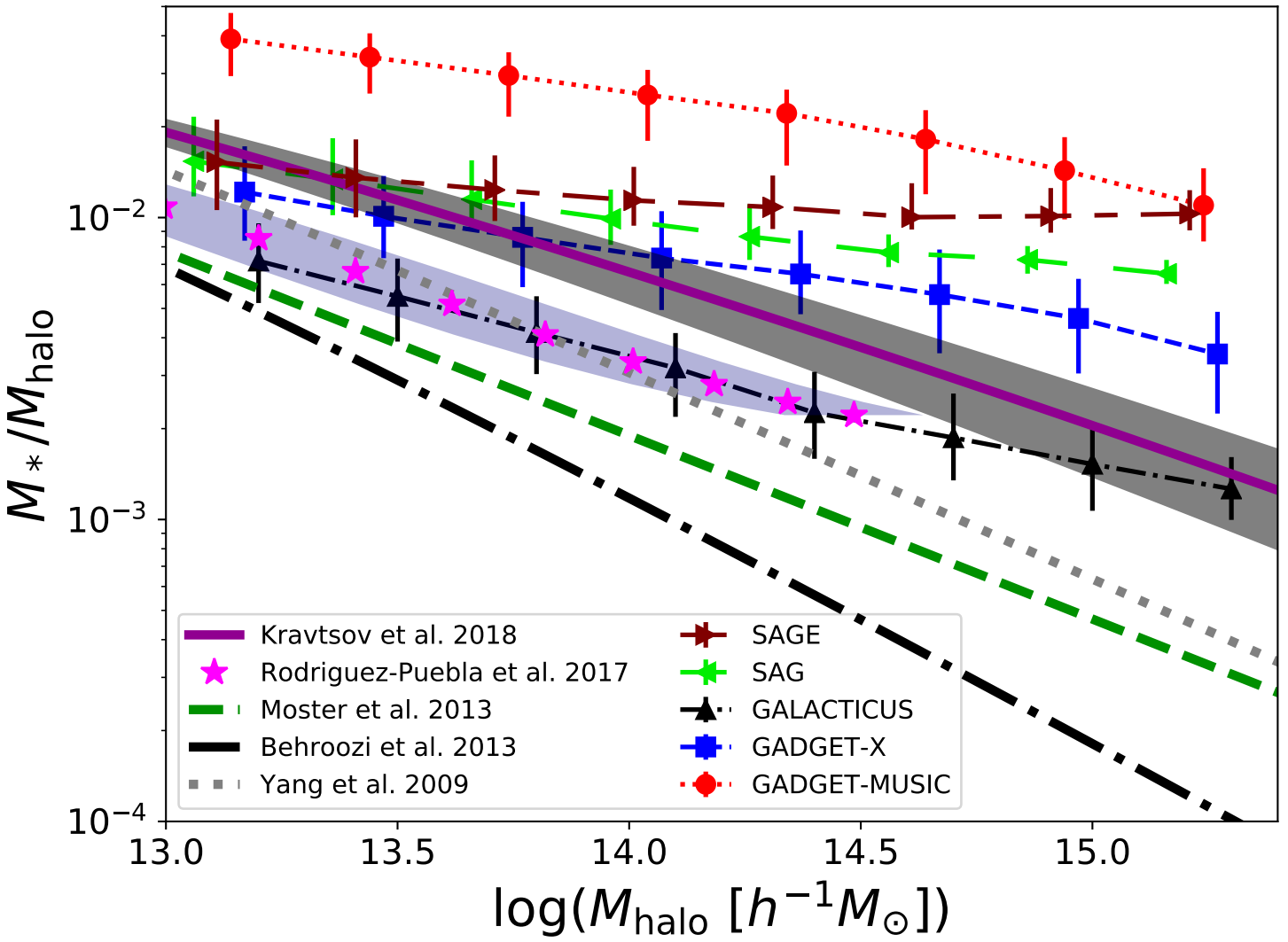
Optical relations: the satellite stellar mass function

The complete sample is used here.



Optical relations: the stellar mass – halo mass relation

The full sample is used here.



Gas scaling relations

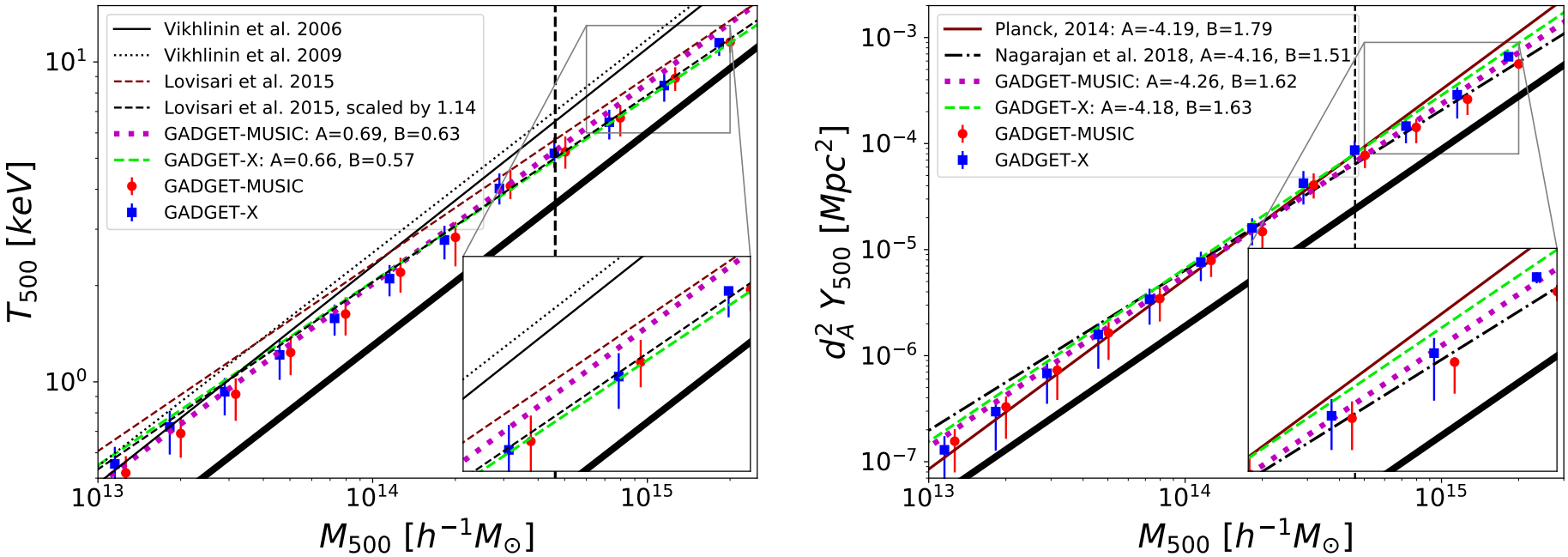


Figure: The T-M (left) and Y-M (right) gas relations.

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Conclusion

- The baryons have a negligible impact on M_{200}, but increase M_{500} for both hydro-simulations.
- $\sim 20\%$ of the complete sample is relaxed clusters, 26% (9%) of the sample is CC for GadgetX (MUSIC).
- The baryon fractions are in agreement with the observations at massive halo masses for GadgetX.
- The optical relations are in agreement with the observations but the galaxies from more models seem to be a little blue. The BCG+ICL is a little bit too massive.
- The gas relations are generally in agreement with observations.

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