Comparison of simulated cluster galaxies at $z \sim 1.0$

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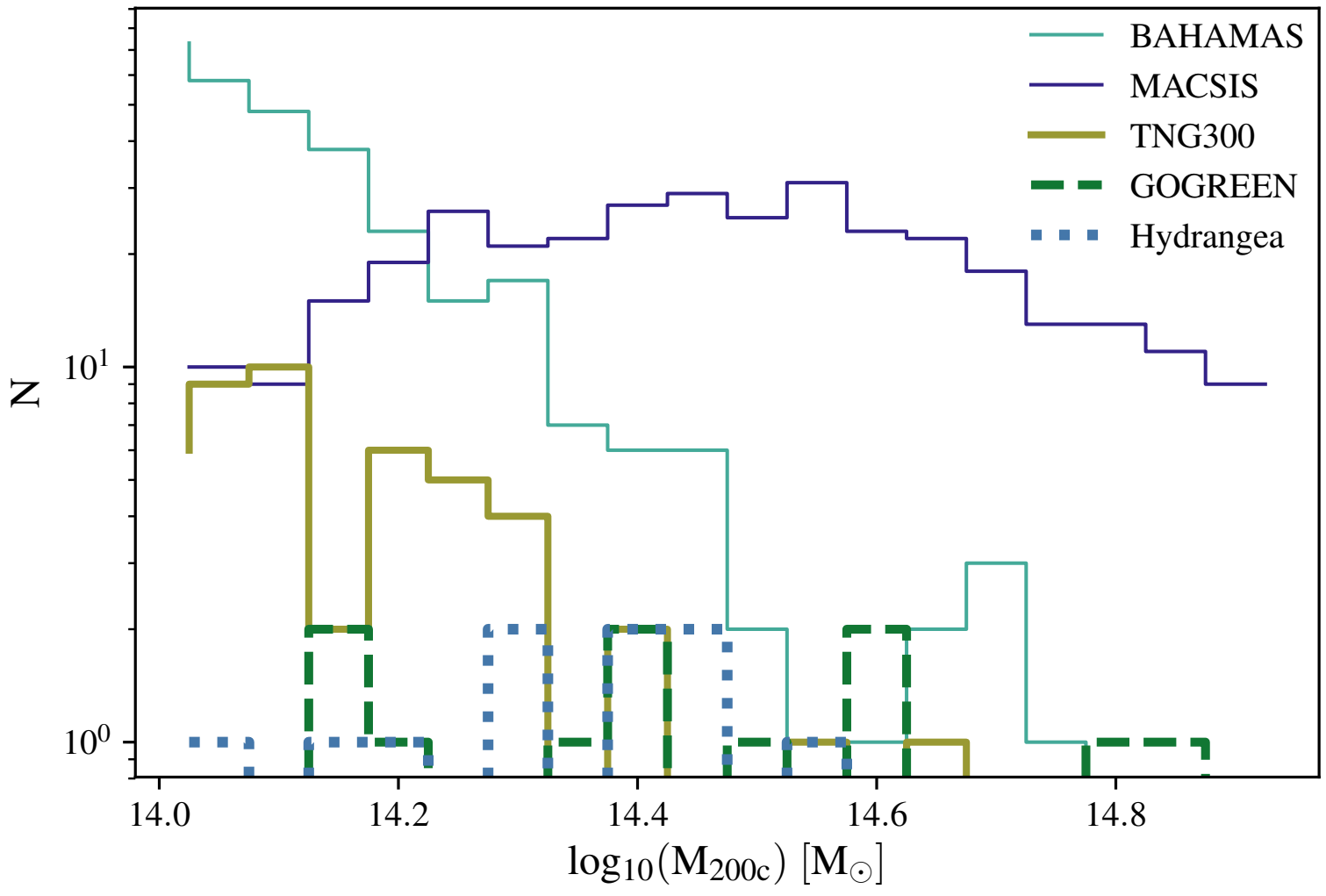
Introduction/Overview

- Environmental processes appear to be different at $\mathrm{z} > 1$
- Simulations have not been calibrated or even tested in this regime (no observations)
- Different simulations likely give varying predictions
- Goal: compare predictions of stellar content of haloes and galaxy quenching at $\mathrm{z} = 1$
- Use available obs. data to compare to where possible
- Simulation-focussed comparison, samples vary for different tests to best suit the given case
  - In all cases, galaxies with $M_* > 10^{10}$ are used
  - $\log_{10}(\mathrm{sSFR}) < -12$ is used to separate star-forming / quenched galaxies.

Simulations

- *SPH-based*
  - **BAHAMAS**: $\mathrm{L_{box}} = 596$ cMpc, $\mathrm{N} = 2 \times 1024^3$, $\mathrm{m_b} = 1.16 \times 10^9 \mathrm{M_\odot}$
  - **MACSIS**: 390 massive haloes selected from a 3.2 Gpc box, re-simulated using BAHAMAS physics
  - **EAGLE AGNdT9**: $\mathrm{L_{box}} = 50$ cMpc, $\mathrm{N} = 2 \times 752^3$, $\mathrm{m_b} = 1.81 \times 10^6 \mathrm{M_\odot}$
  - **Hydrangea**: 11 Haloes ($\log_{10}(\mathrm{M_{200c}}/\mathrm{M_\odot}) \geq 14.0$) using AGNdT9 physics
- *AMR-based*
  - **TNG300-1**: $\mathrm{L_{box}} = 303$ cMpc, $\mathrm{N} = 2 \times 2500^3$, $\mathrm{m_b} = 1.1 \times 10^7 \mathrm{M_\odot}$

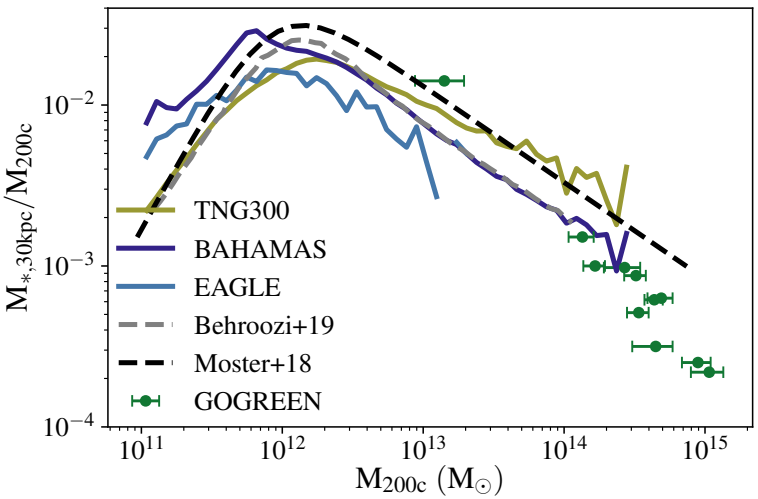


Halo mass distribution of all simulations compared to GOGREEN.
EAGLE AGNdT9 does not have any haloes $\log_{10}(M_{200c}/M_\odot) \geq 14.0$

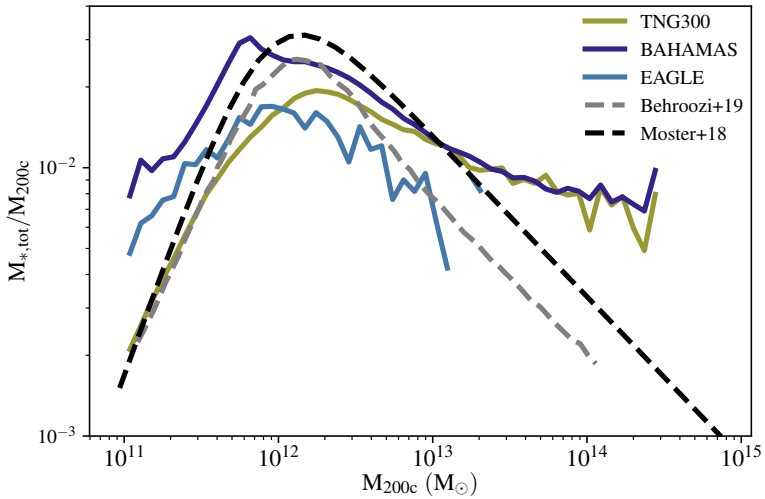
Tests

- Stellar content
  - Field central $\mathrm{M_*} - \mathrm{M_{200c}}$
  - Cluster $(\mathrm{R} \leq \mathrm{r_{200c}})$ $\mathrm{M_*} - \mathrm{M_{200c}}$
  - Cluster central $\mathrm{M_*} - \mathrm{M_{200c}}$
  - Total GSMF
- Galaxy quenching
  - SF/Q GSMF
  - $\mathrm{f_q} - \log_{10}(\mathrm{M_*}/\mathrm{M_\odot})$
  - Quenched fraction excess

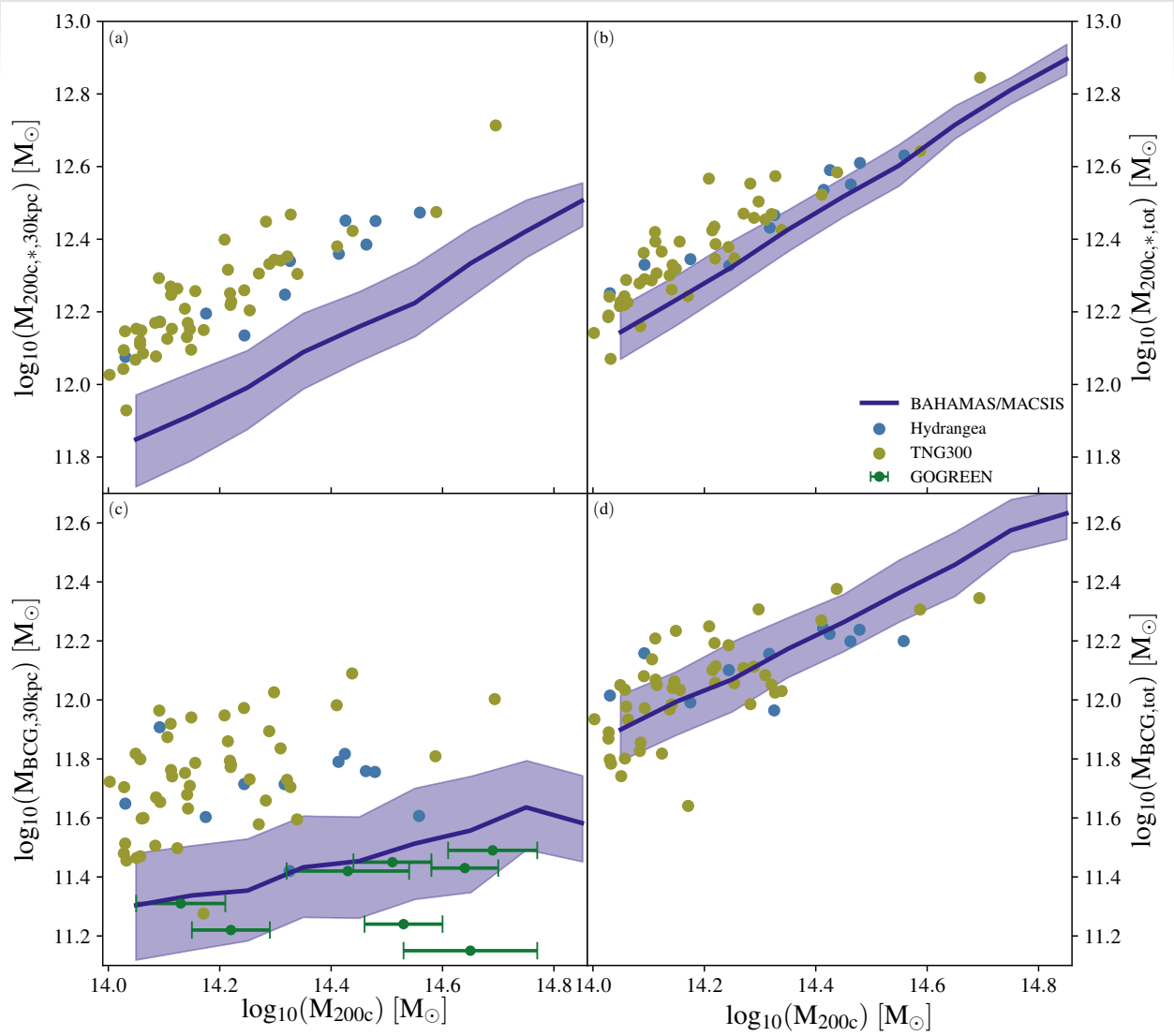
Field (central) $\mathrm{M}_* - \mathrm{M}_{200c}$



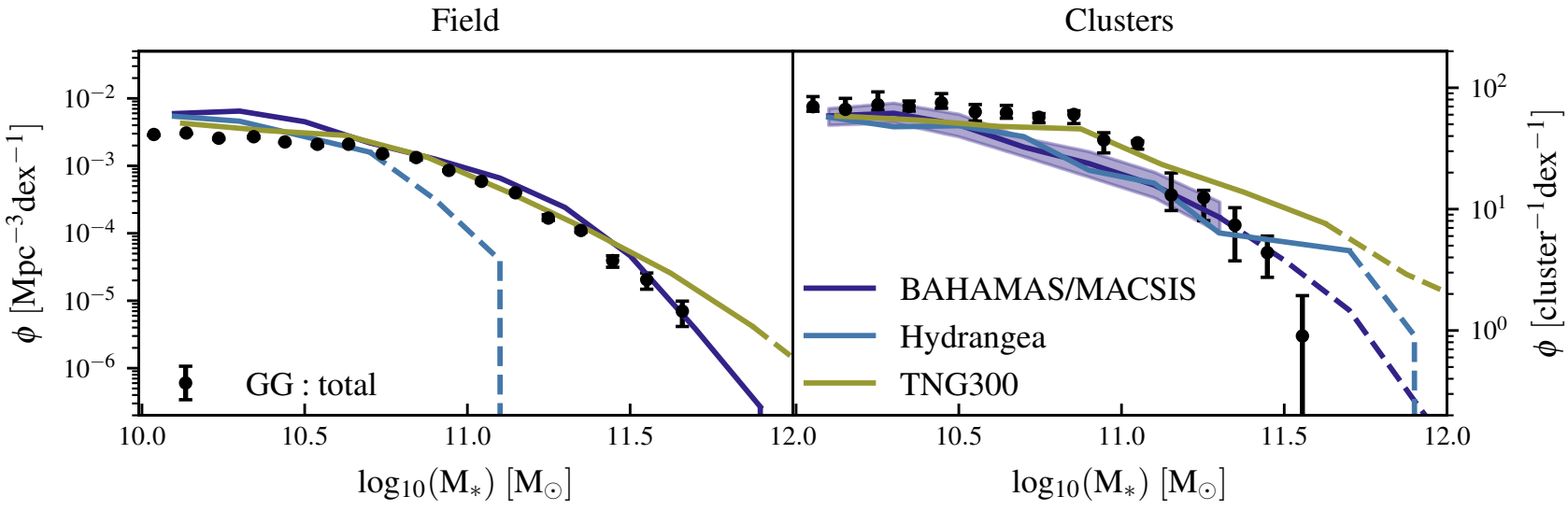
(a) Stellar mass of all centrals, measured within a 3D aperture of 30 kpc. Comparing to abundance matching results of Moster et al. 2018 and Behroozi et al. 2019.



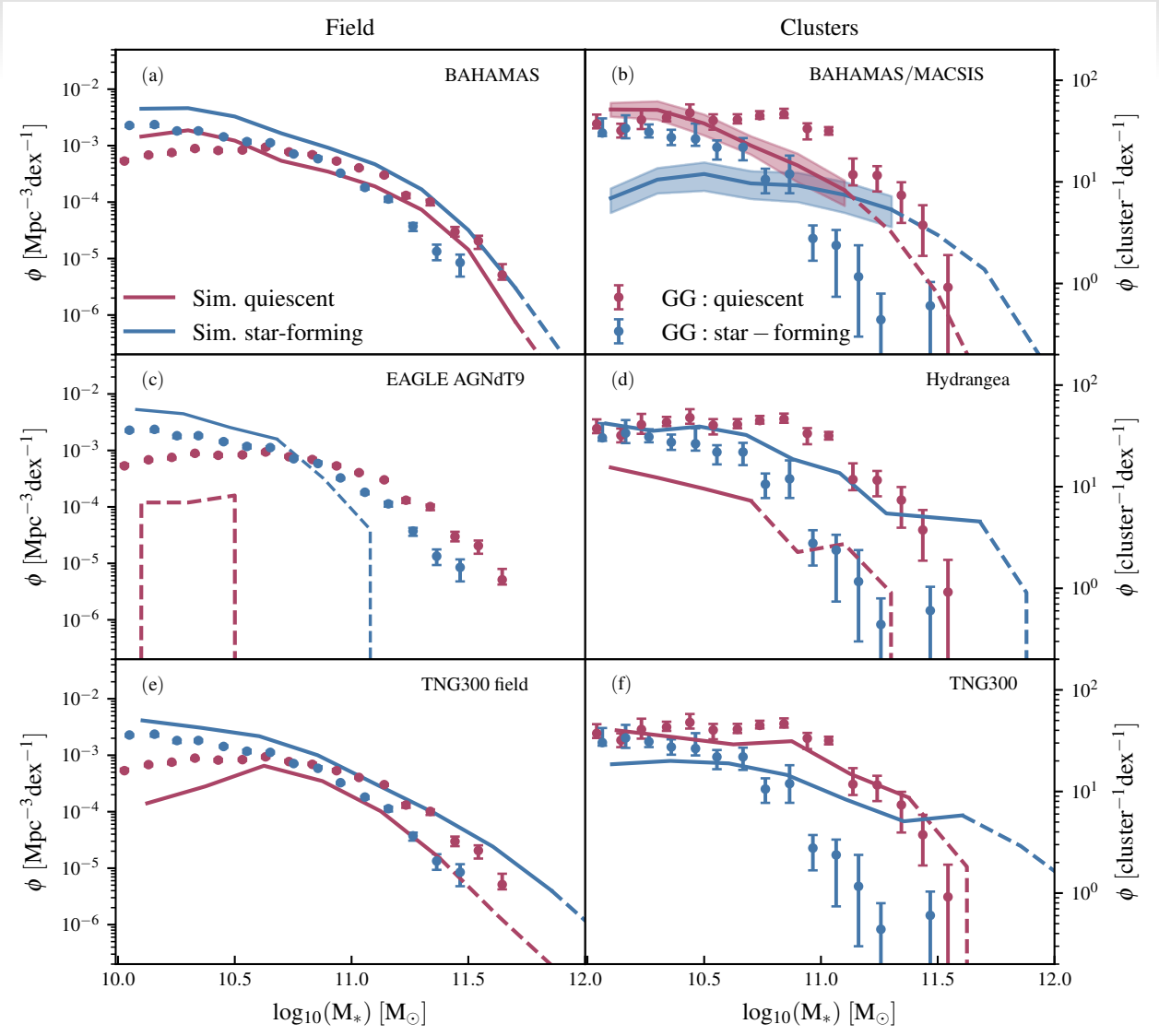
(b) The same but stellar mass is not limited by an aperture.



Stellar mass content of clusters (top row) and BCGs (bottom). With 30 kpc aperture (left) and without (right). All haloes with $\log_{10}(\mathrm{M_{200c}}/\mathrm{M_\odot}) \geq 14.0$ are used.



Sims match GG total GSMF reasonably well, BCGs are too massive in all (and star-forming). SF/Q trends very different.



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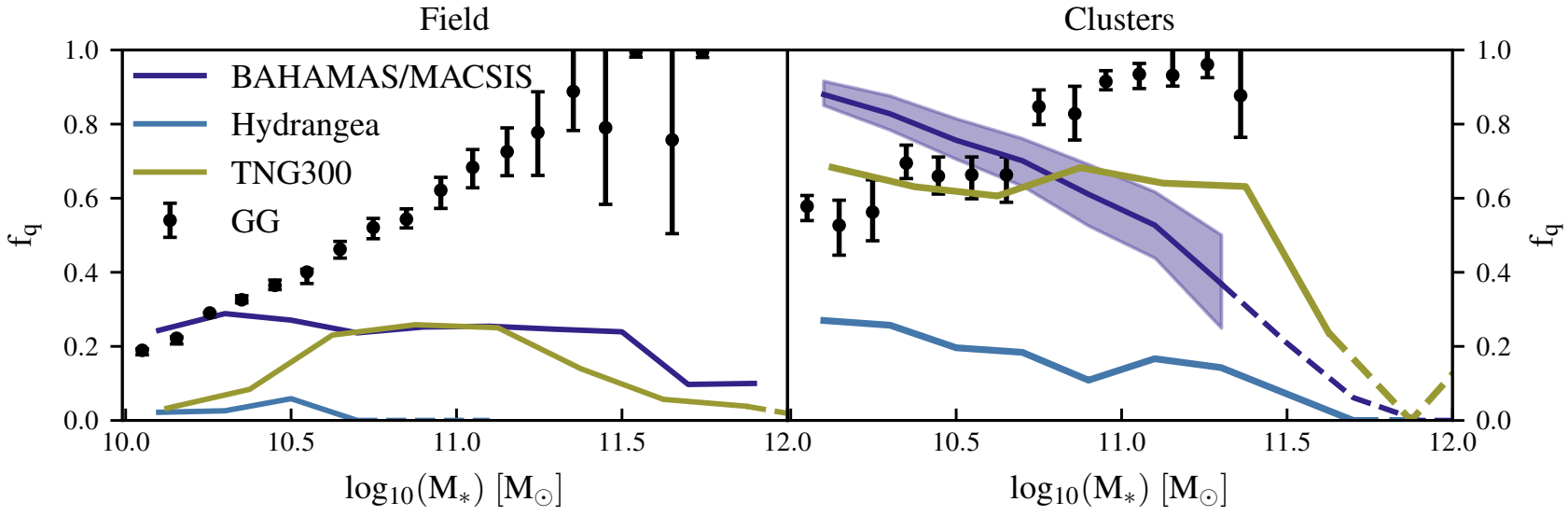
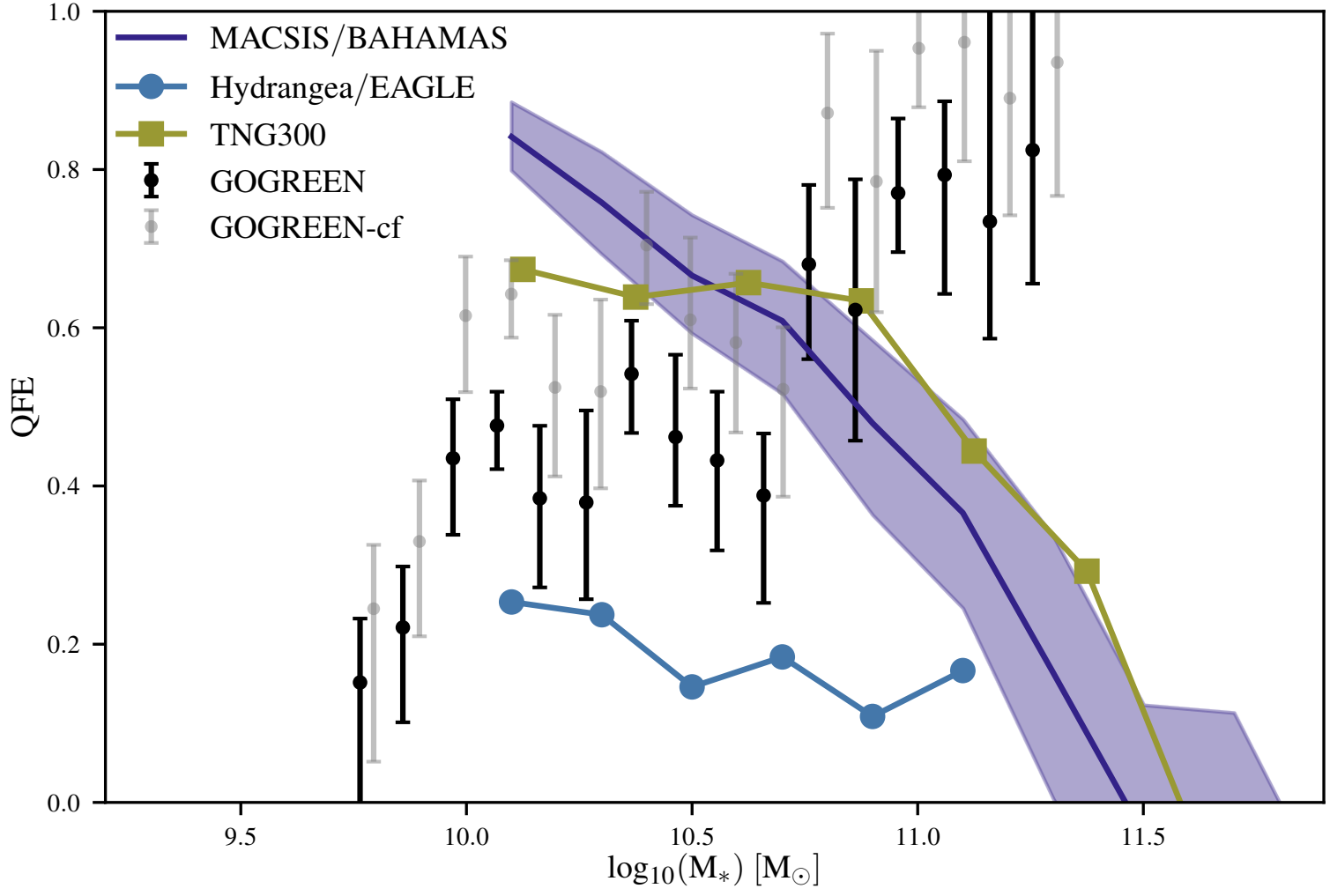
$f_q - \log_{10}(M_*)$

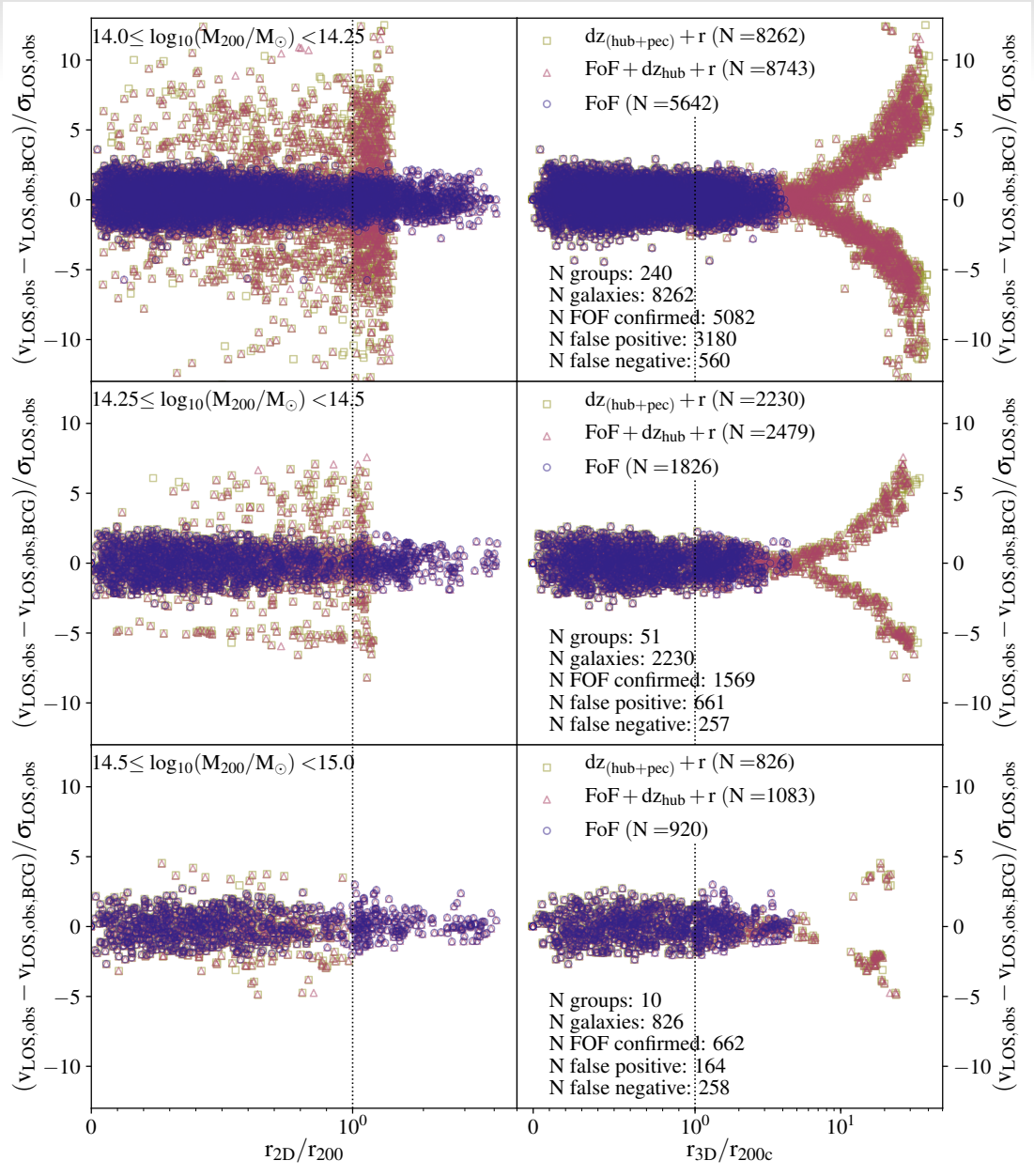

Field
Clusters
BAHAMAS/MACSIS
Hydrangea
TNG300
GG
f_q
$\log_{10}(M_*)$ [$M_\odot$]
1.0
0.8
0.6
0.4
0.2
0.0
10.0
10.5
11.0
11.5
12.0

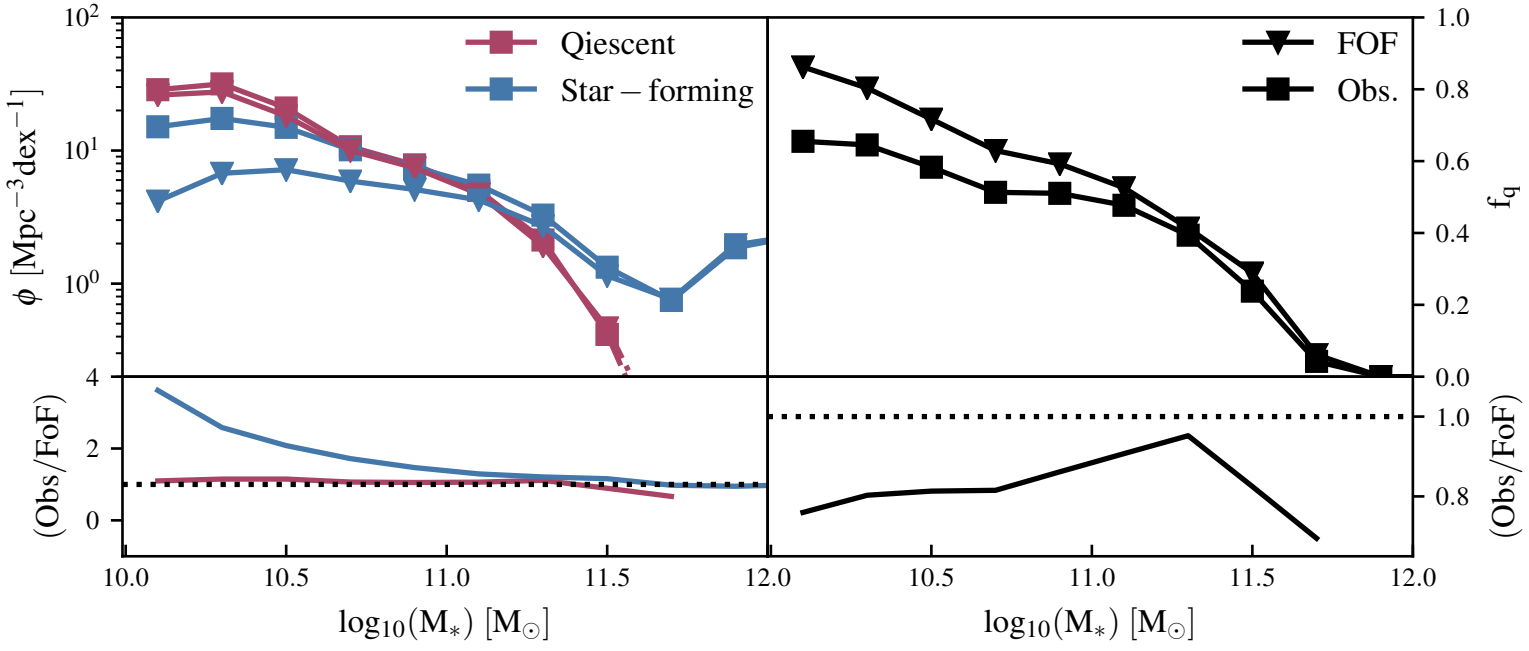


Quenched fraction excess. All simulations get the trend wrong at high M_*. TNG300 is least wrong at intermediate M_*, just like fq.

Conclusions

- **Stellar content** of field centrals, halo, cluster BCG in **reasonable agreement** between simulations and 'observations'
- BAHAMAS galaxies (especially BCGs) are less compact relative to TNG300, Hydrangea; but agree with GOGREEN. Unexpected because it has the lowest resolution.
- **Total GSMF** more-or-less **consistent** between models.
- **Big differences** seen when galaxies are **split up by type** (GSMF and radial profiles).
- **Centrals** are **star-forming** in all cases: an indication of overcooling.
- **None** of the models capture the $\mathbf{f_q - \log_{10}(M_*)}$ relation correctly.
- The same applies to QFE.
- Observational membership selection under-estimates $\mathrm{f_q}$ but not enough to change conclusions.
- Hydro simulations do not capture galaxy quenching at $\mathrm{z} \sim 1$


14.0≤ log10(M200/M⊙) <14.25
dz(hub+pec) + r (N =8262)
FoF + dzhub + r (N =8743)
FoF (N =5642)
N groups: 240
N galaxies: 8262
N FOF confirmed: 5082
N false positive: 3180
N false negative: 560
14.25≤ log10(M200/M⊙) <14.5
dz(hub+pec) + r (N =2230)
FoF + dzhub + r (N =2479)
FoF (N =1826)
N groups: 51
N galaxies: 2230
N FOF confirmed: 1569
N false positive: 661
N false negative: 257
14.5≤ log10(M200/M⊙) <15.0
dz(hub+pec) + r (N =826)
FoF + dzhub + r (N =1083)
FoF (N =920)
N groups: 10
N galaxies: 826
N FOF confirmed: 662
N false positive: 164
N false negative: 258
(vLOS,obs − vLOS,obs,BCG)/σLOS,obs
r2D/r200
r3D/r200c



Quenched fraction excess. All simulations get the trend wrong at high M_*. TNG300 is least wrong at intermediate M_*, just like fq.