ELUCID VIII: SIMULATING THE COMA GALAXY CLUSTER TO CALIBRATE MODEL AND UNDERSTAND FEEDBACK

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Introduction

Simulation models:

IllustrisTNG, EAGLE, SIMBA, FIRE ...

Constrain models on cluster scales

observation data: X-ray, tSZ ...

Simulations for clusters:

	TNG-Cluster	Cluster-EAGLE(C-EAGLE)	The Three Hundred Project
$N_{cluster}$	352	30	324
Model	TNG	EAGLE	Gadget-MUSIC Gadget-X Gizmo-Simba
$m_{dm}/M_{\odot}$	6.1×10^7	9.7×10^6	1.87×10^9
$m_b/M_{\odot}$	1.2×10^7	1.8×10^6	2.36×10^8

Required computing power $\propto$ $N_{cluster} * N_{models} / m_{dm}$

Constrained simulations: ELUCID : Coma cluster (why Coma?)

Simulations

Constrained simulations: ELUCID

L = 500 h^{-1}Mpc

$m_{dm} = 4.4 \times 10^7 M_\odot$

$m_{gas} = 9.14 \times 10^6 M_\odot$

Coma cluster:

$M_{200c} = 7.52 \times 10^{14}\ h^{-1} M_\odot$

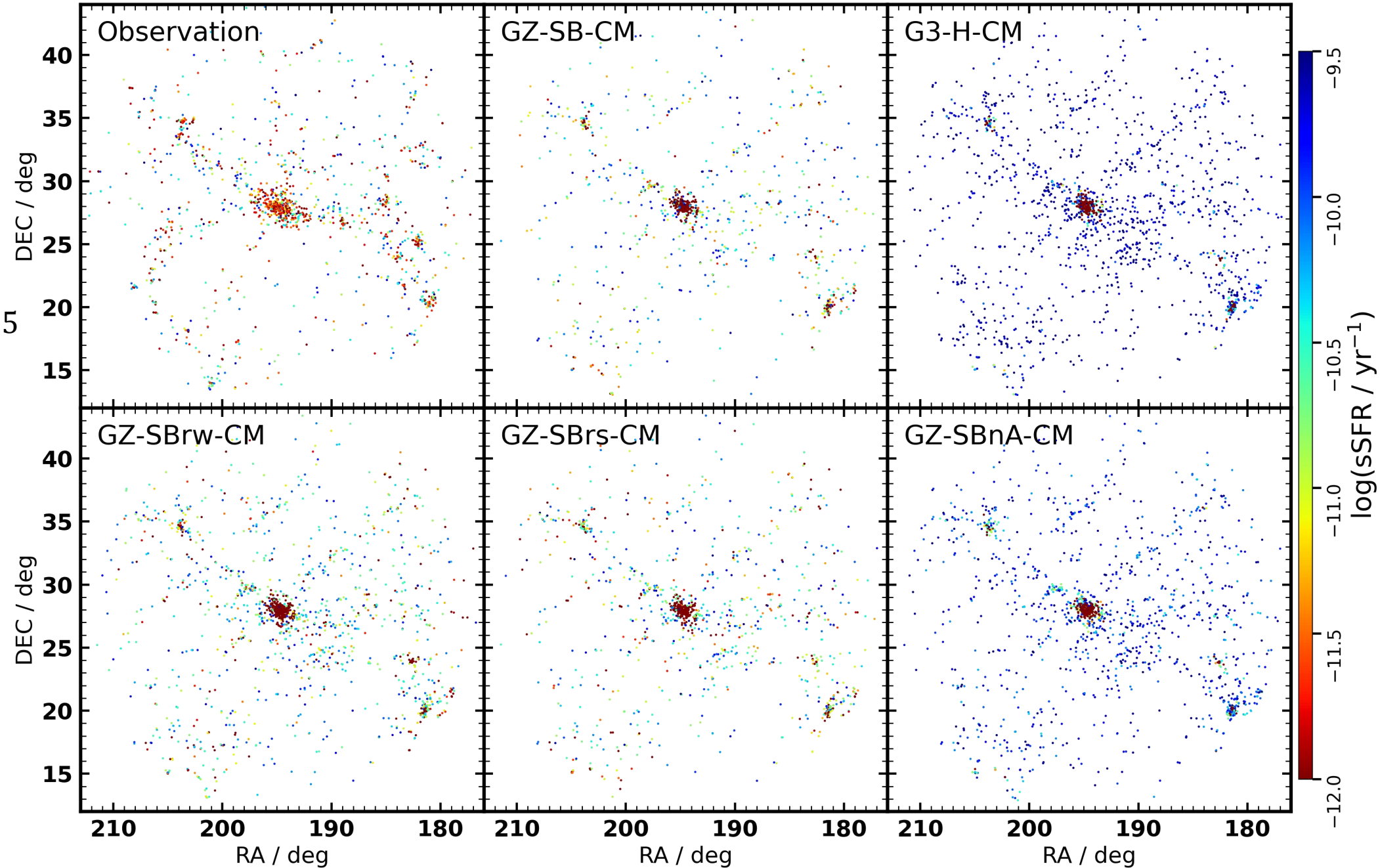
$R_{200c} = 1.48\ h^{-1}$Mpc

Simulation	Structure	HIR Radius	Code	SF model	AGN model
GZ-SB-CM	Coma	20	GIZMO	SIMBA	SIMBA
GZ-SBrw-CM	Coma	20	GIZMO	high SF& strong SN	weak Jet
GZ-SBrs-CM	Coma	20	GIZMO	high SF& strong SN	strong Jet
GZ-SBnA-CM	Coma	20	GIZMO	SIMBA	no AGN
G3-H-CM	Coma	30	GADGET-3	Huang et al. (2020)	no AGN
G3-H-VD	Void	40	GADGET-3	Huang et al.(2020)	no AGN

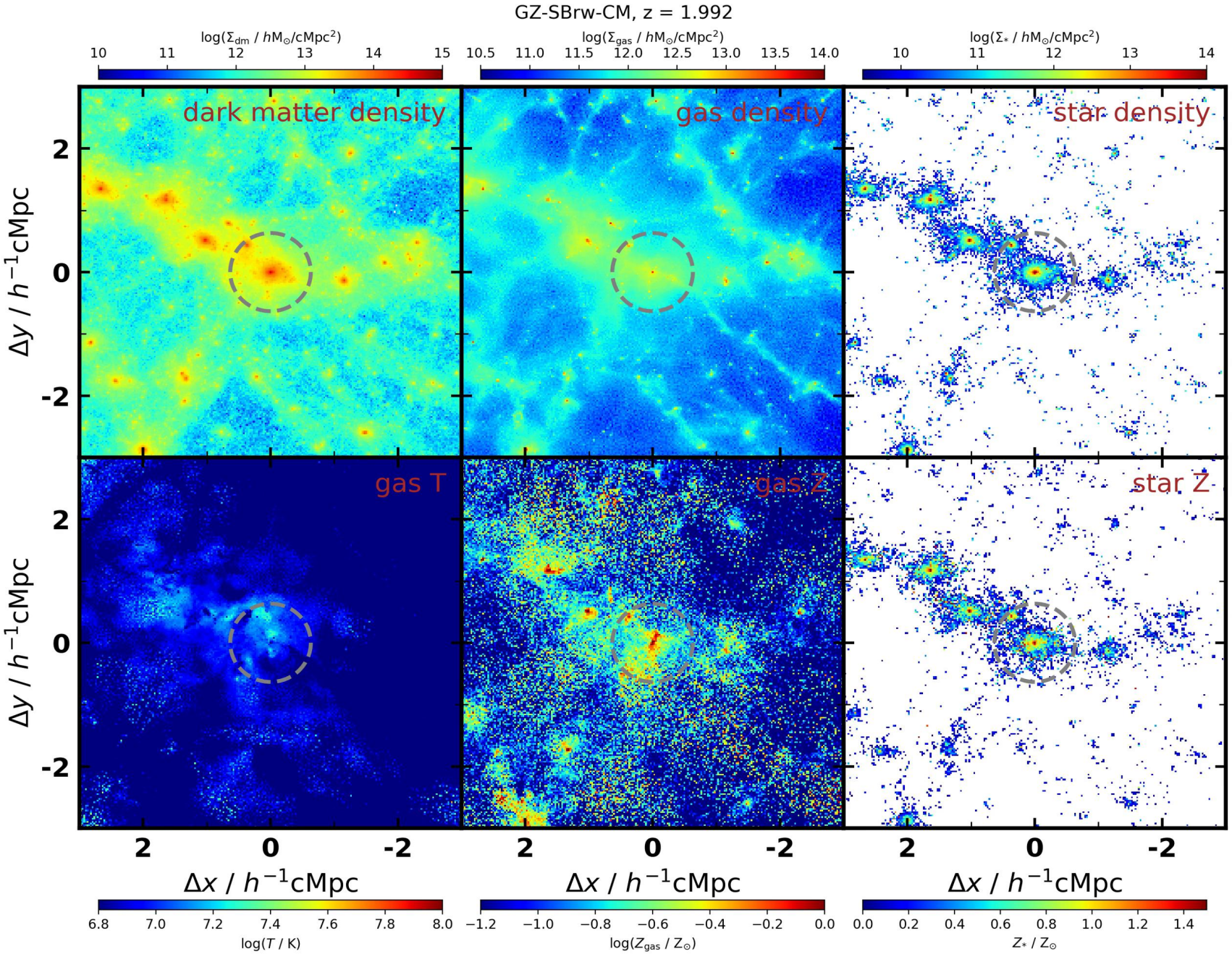
2D distribution of galaxies

R < 20 Mpc/h

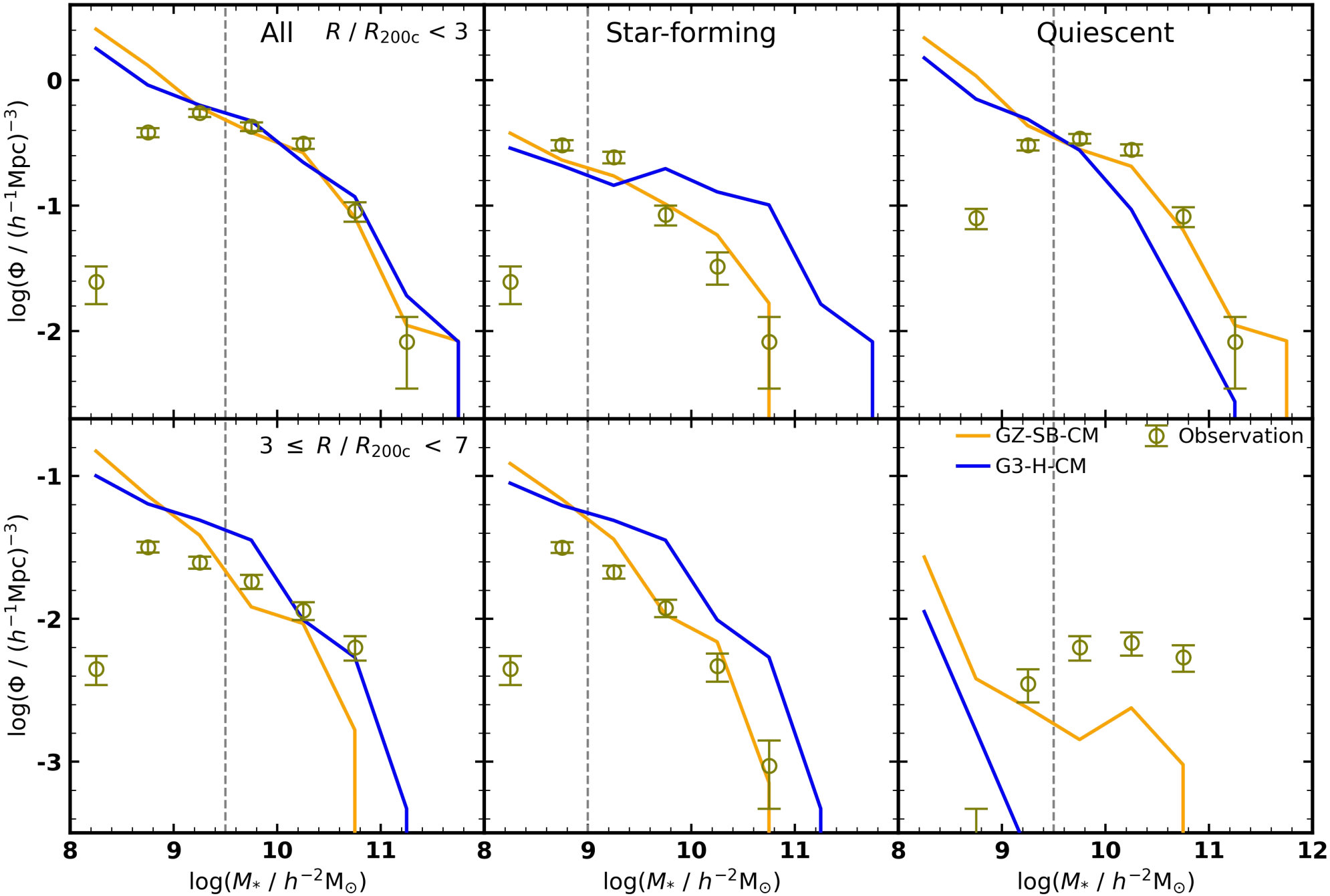
$\log(M_*/h^{-2}M_\odot) > 9.5$



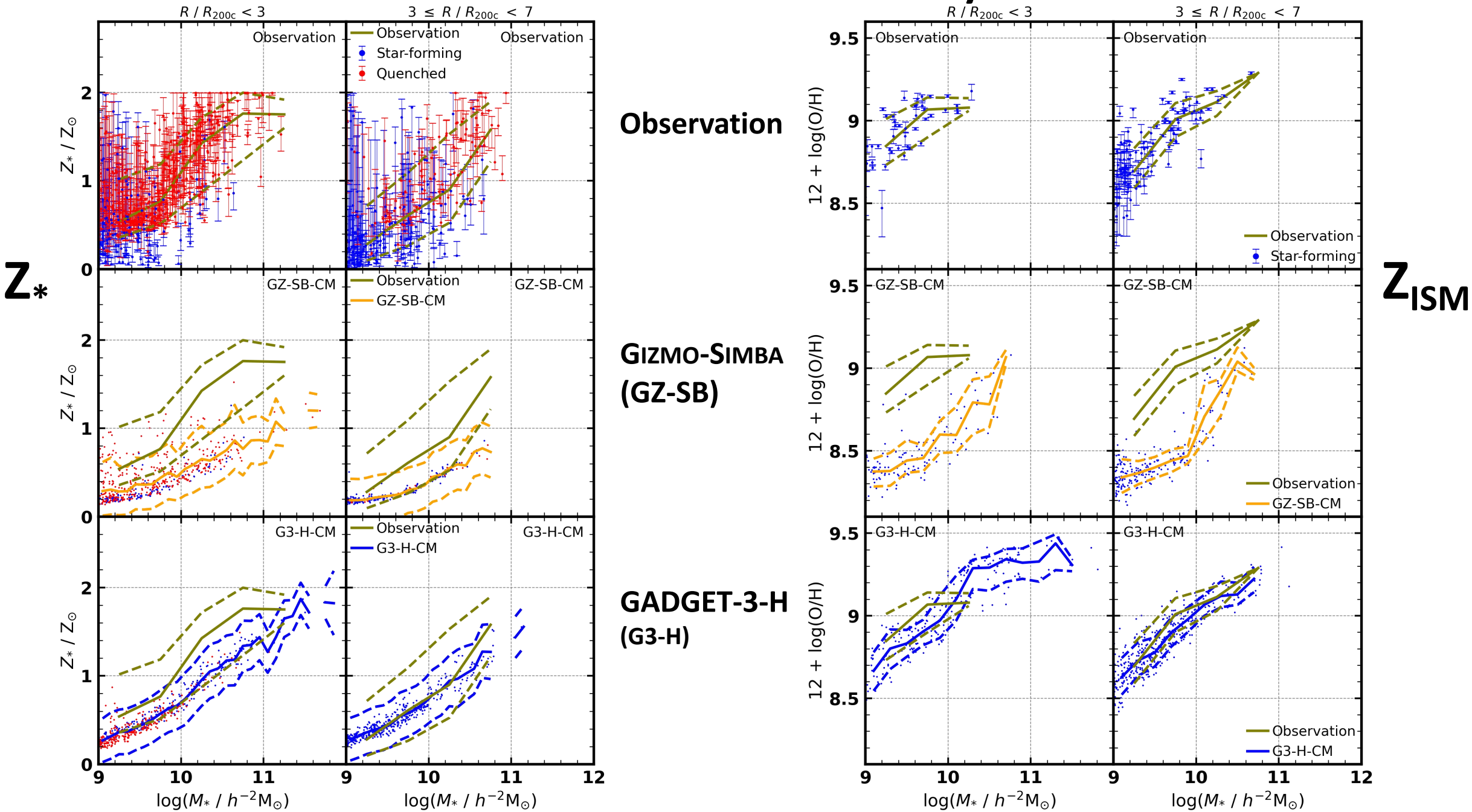
The Coma cluster in GZ-SBrw-CM



GIZMO-SIMBA and GADGET-3-H: SMF

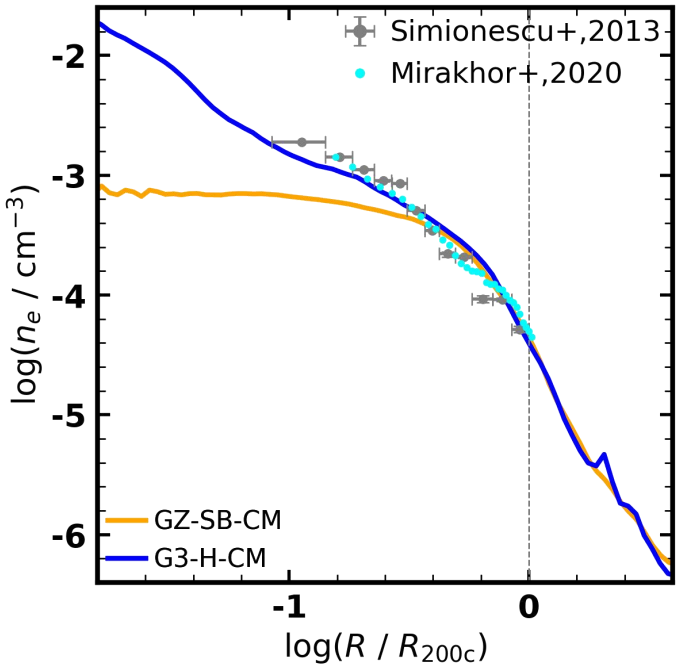


GIZMO-SIMBA and GADGET-3-H: stellar & ISM metallicity

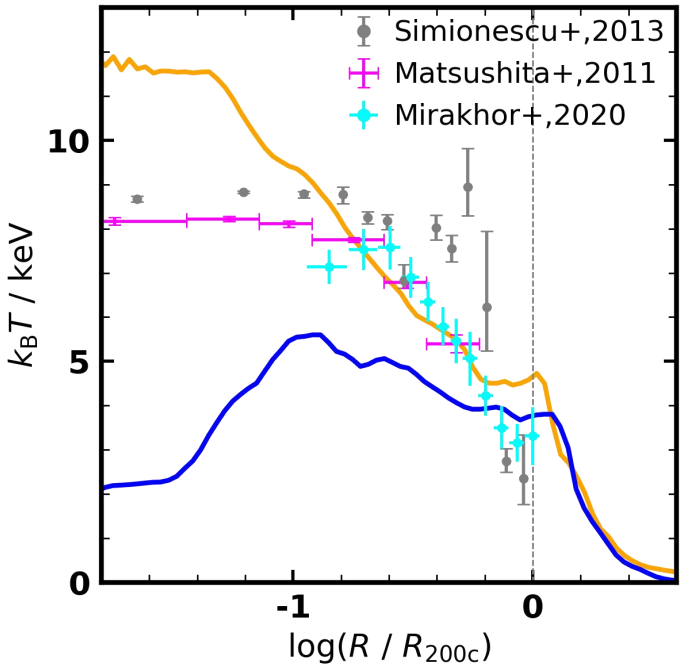


GIZMO-SIMBA and GADGET-3-H: ICM profiles

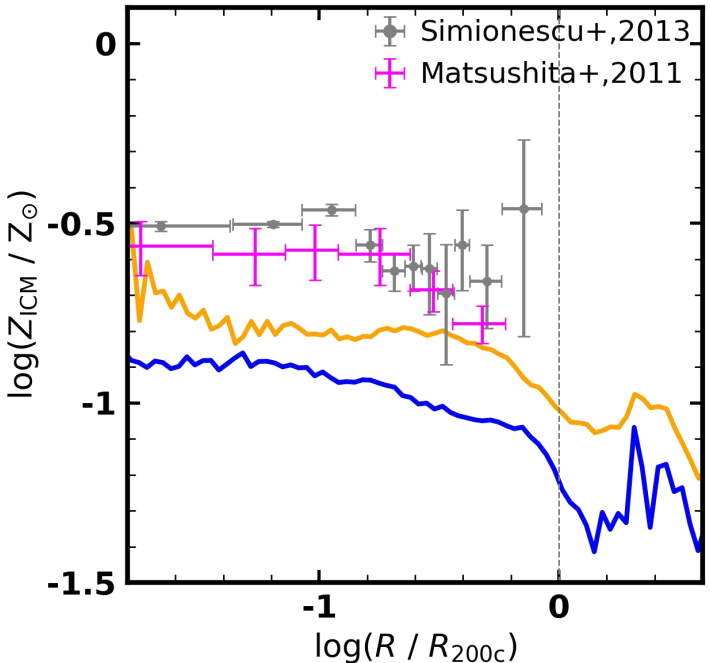
electron number density



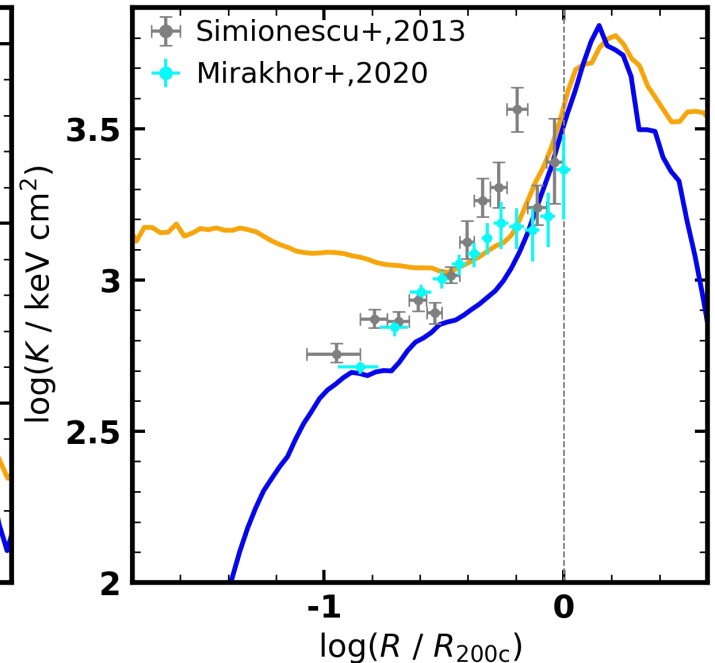
temperature



metallicity

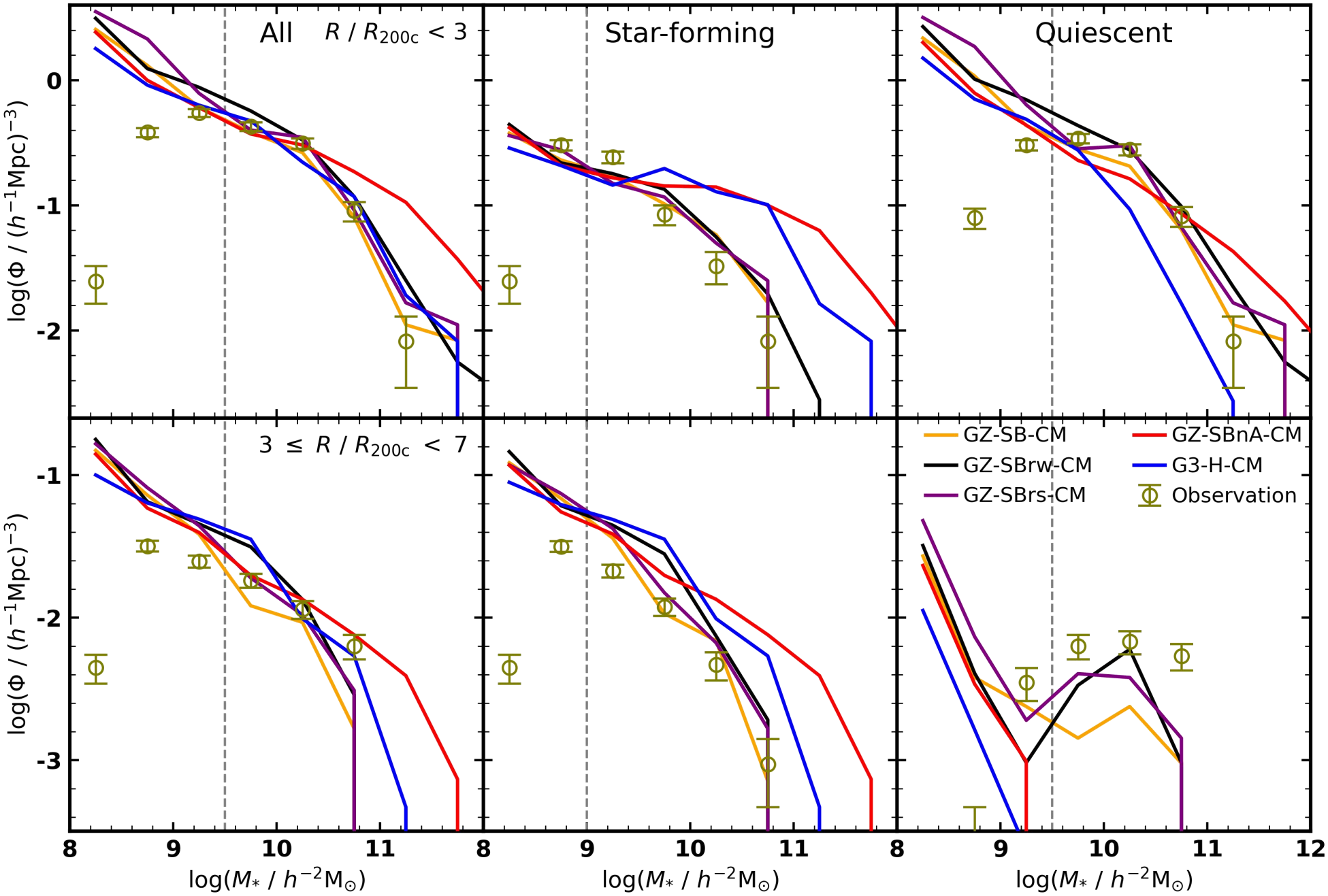


entropy

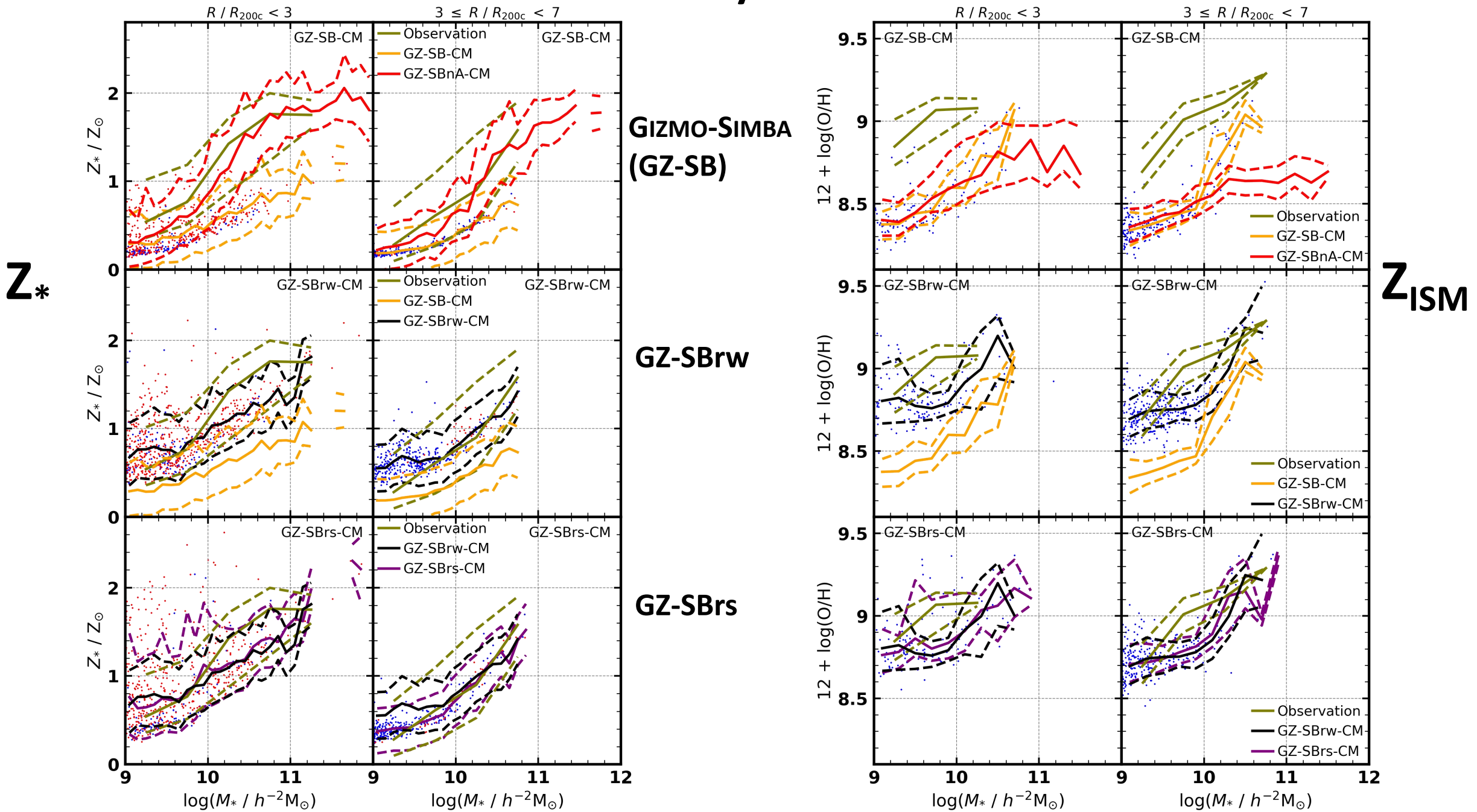


Modified models: SMF

Simulation	SF model	AGN model
GZ-SB-CM	SIMBA	SIMBA
GZ-SBr1-CM	high SF& strong SN	weak Jet
GZ-SBr2-CM	high SF& strong SN	strong Jet
GZ-SBnA-CM	SIMBA	no AGN

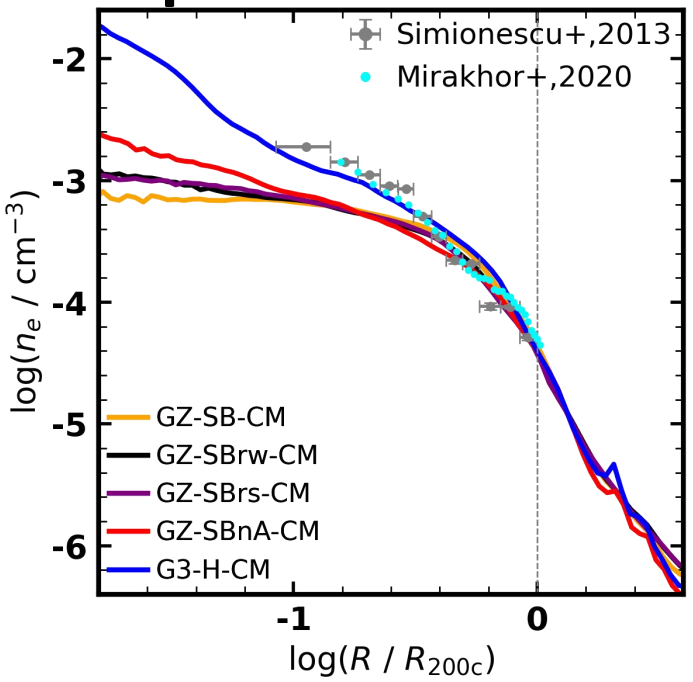


Modified models: stellar & ISM metallicity

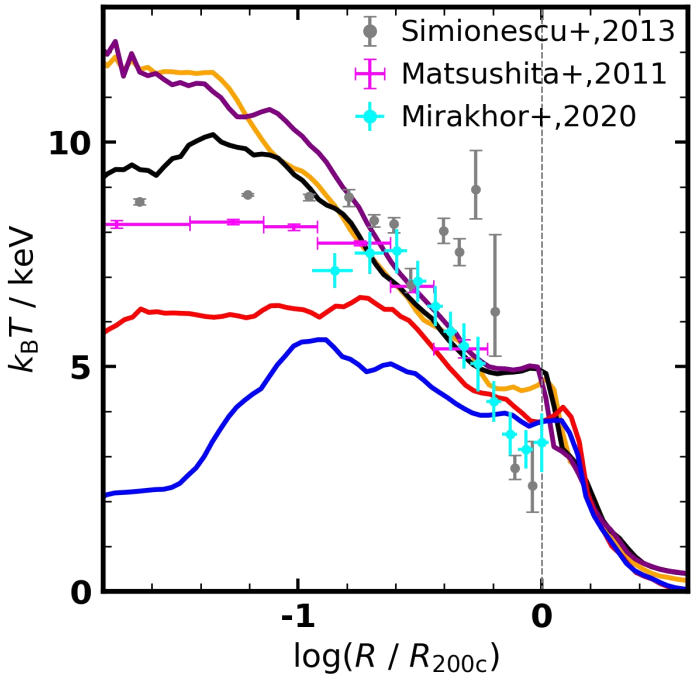


Modified models: ICM profiles

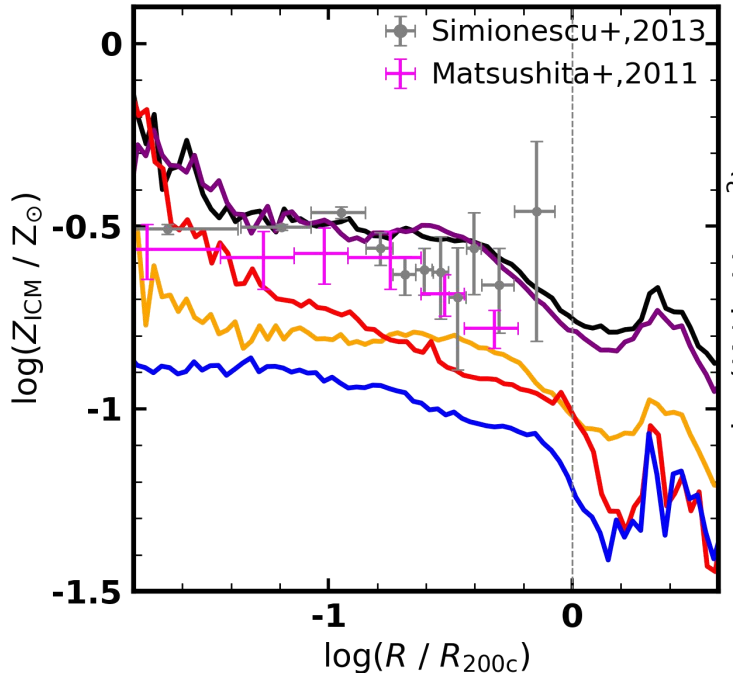
electron number density



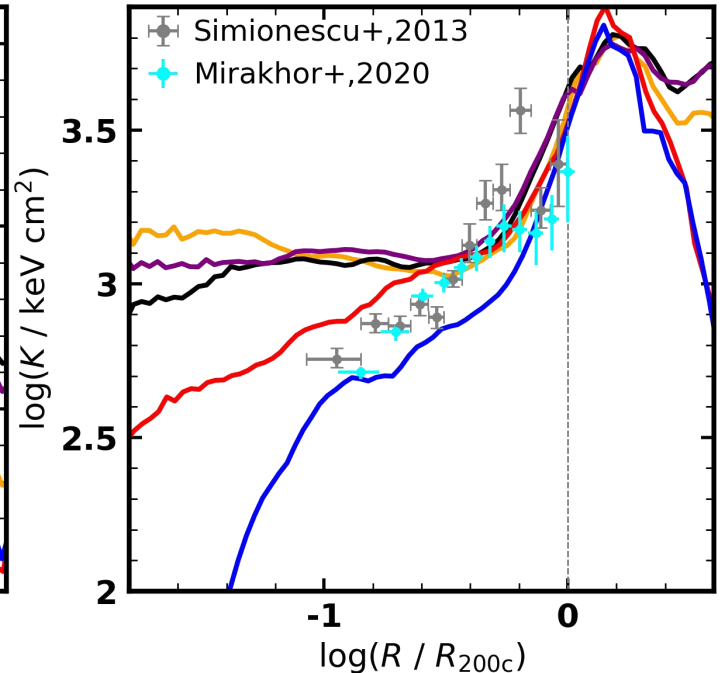
temperature



metallicity



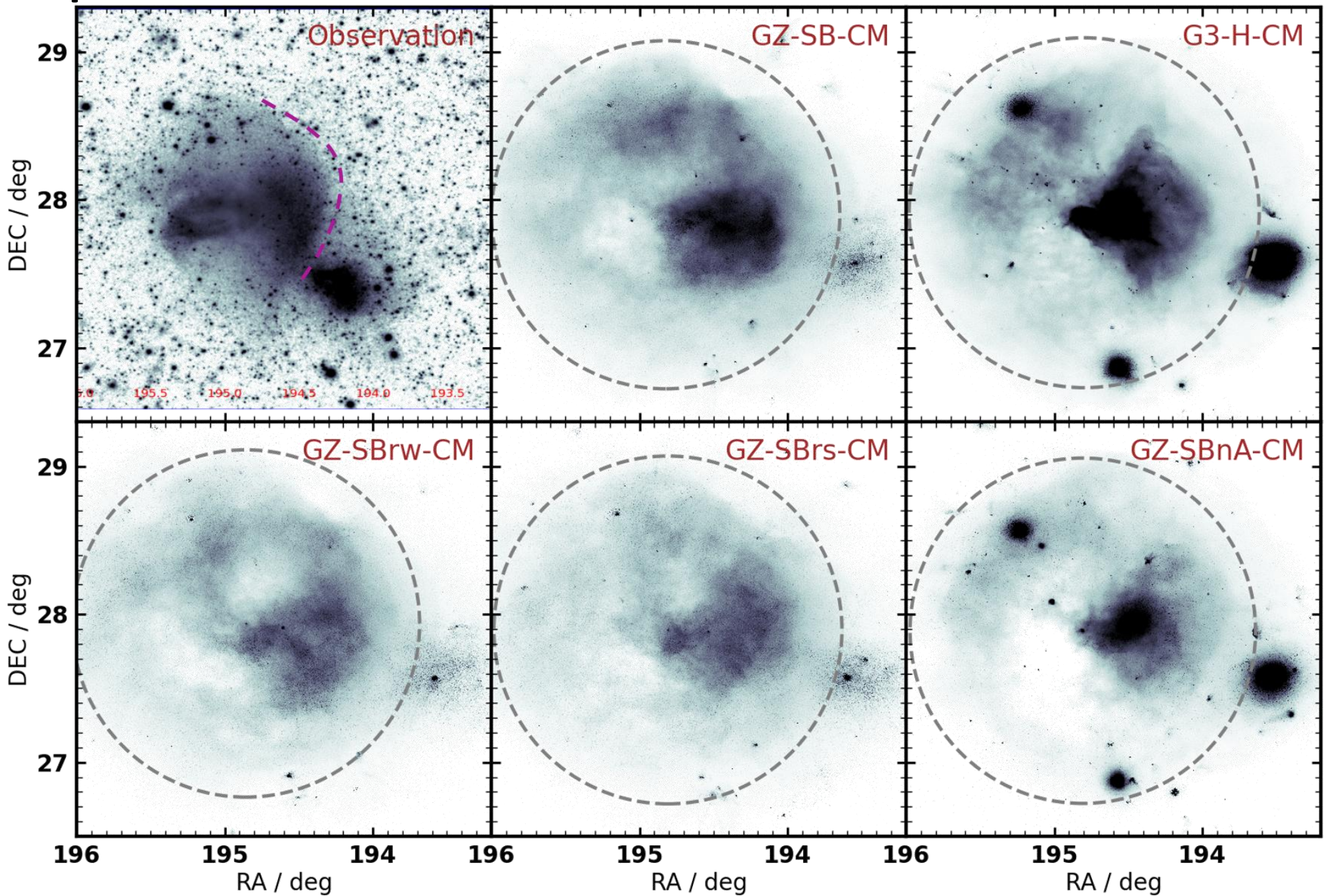
entropy



Flat-fielded X-ray map of Coma cluster

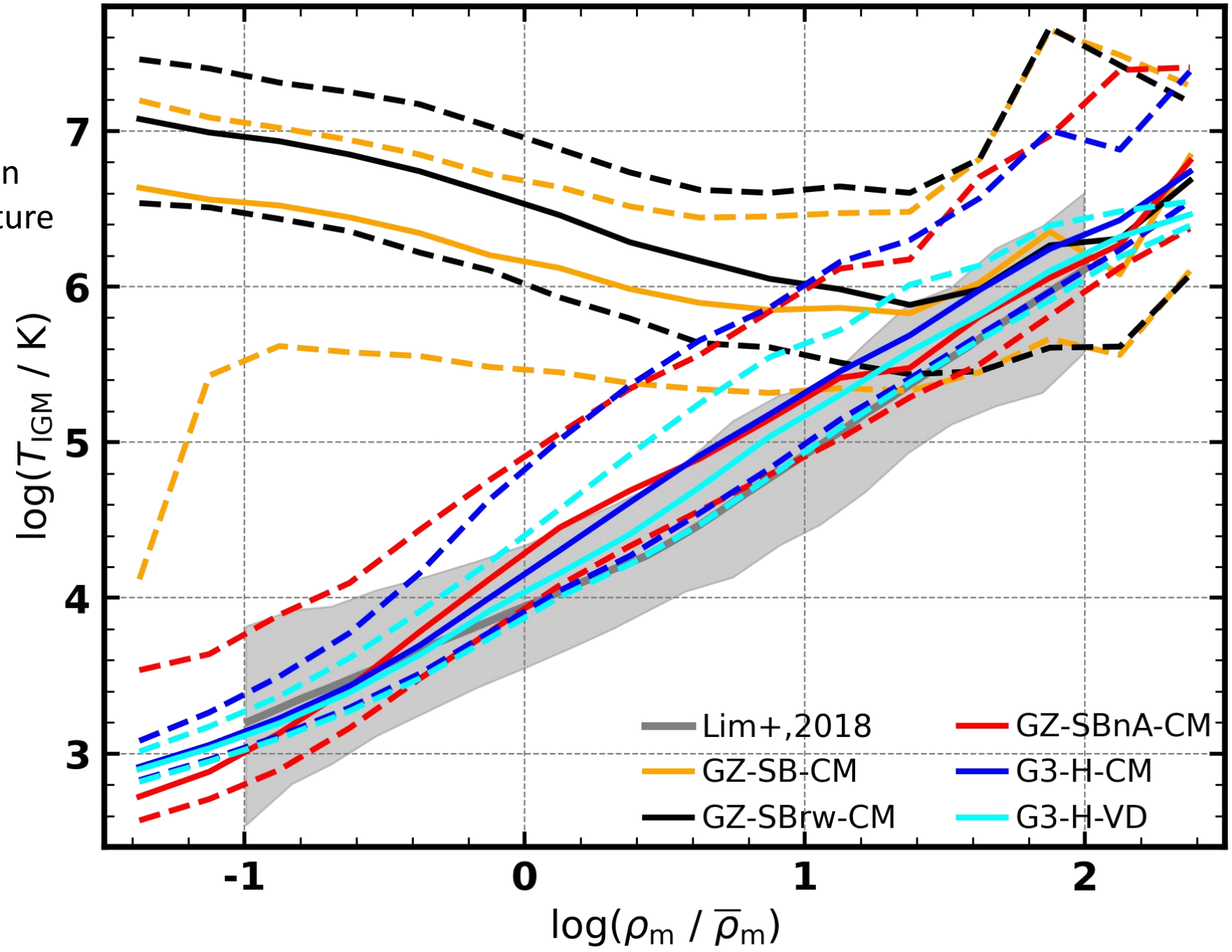
eROSITA data from Churazov et al. (2021)

$$f(r) = 1 + \frac{c}{\left[1 + (r/r_c)^2\right]^{3\beta-\frac{1}{2}}}$$



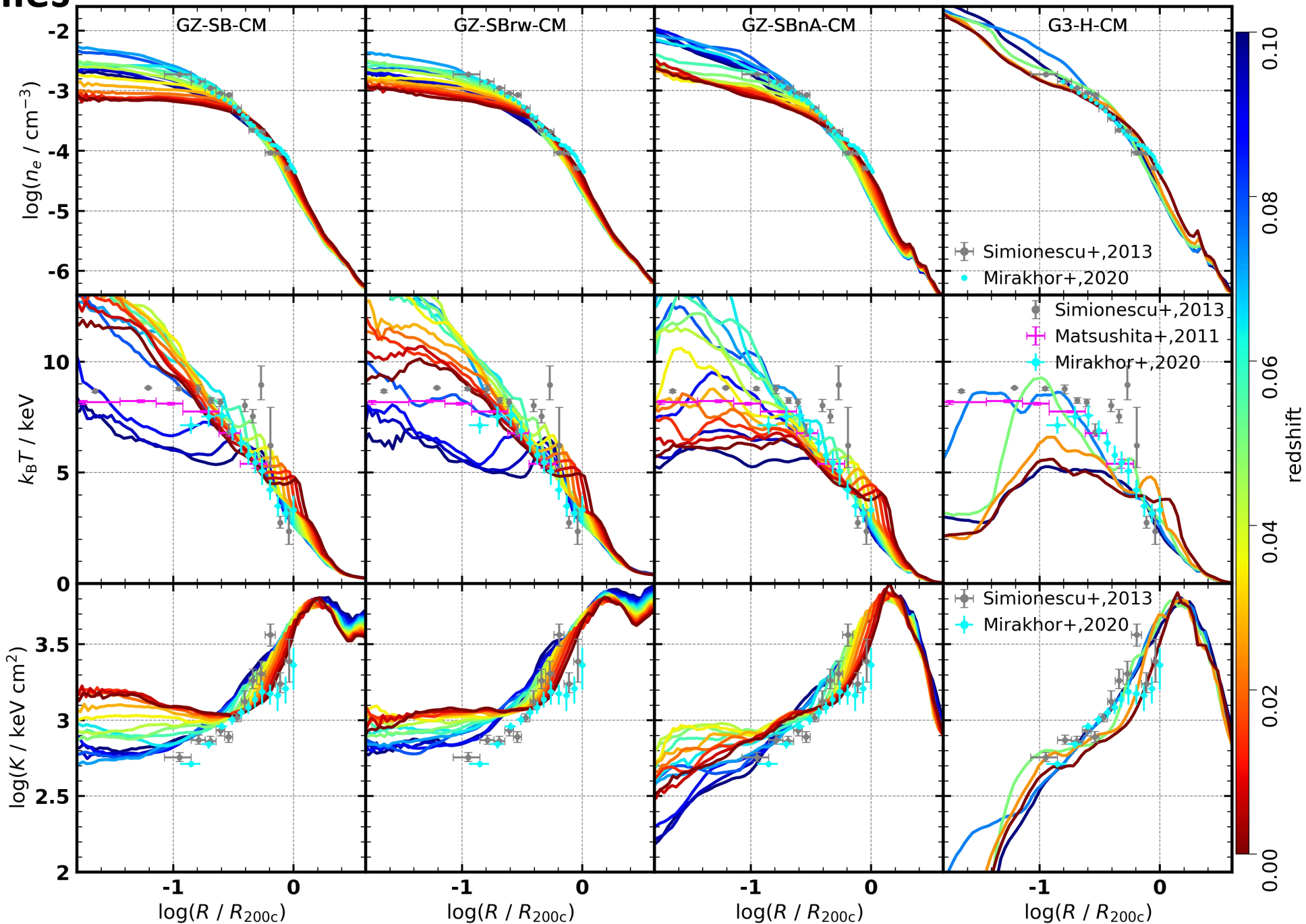
T_{IGM} - ρ_m relation

The IGM in low-density regions can be heated to a very high temperature in simulations with AGN.



History of ICM profiles

Uncertainty of reconstruction



Summary

- Generally, the GZ-SB model is able to reproduce the observed stellar mass function in the Coma region, except that it significantly underestimates the population of quiescent galaxies in the low-density region. The G3-H model is able to accurately reproduce the total SMF in both low- and high-density regions, but it predicts too many star-forming galaxies and too few quiescent galaxies.

- Our new model assuming higher star formation rate and supernova feedback strength matches the observed metallicities in stars, ISM and ICM better than the fiducial model.

- Our two non-AGN simulations, GZ-SBnA-CM and G3-H-CM, produce similar features of a bow-like shock at similar locations in X-ray maps, while all simulations with AGN feedback basically fail to recover these features.

- The two non-AGN simulations predict a T_{IGM}-ρ_m relation that is consistent with the observation within the observational uncertainty. But in simulations with AGN , the IGM in low-density regions can be heated to a very high temperature.

- Quenching mechanisms may only operate on relatively small scales and do not significantly alter the gas properties on the cluster and larger scale