On the Growth of Diffuse Light from Simulations of Galaxy Clusters

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Abstract

Deep surface photometry reveals the presence in a good number of galaxy clusters, as well as in their smaller counterparts, galaxy groups, of an extended, diffuse luminous component that fills the space between galaxies. This intracluster light (ICL) is believed to originate from the disruption of the outermost regions of the galaxies that make up these systems.
Our aim in this work is to make use of controlled numerical simulations of pre-virialized clusters to study the formation of the diffuse ICL, and investigate its potential to describe the assembly history of such systems of galaxies.
We are currently using our simulations to track the growth of the ICL over cosmic time, tracing its evolution across clusters spanning a range of masses and galaxy memberships. Here, we present our first results, where we analyzed the relationship of ICL formation with the mass and size of the brightest galaxy in the cluster and its dependence on both the merger fraction and the efficiency of interactions.

Introduction

The diffuse ICL is a pervasive feature of galaxy associations consisting of an extended low-surface-brightness component that permeates their intergalactic medium. For the most part, it is concentrated around the brightest cluster galaxy (BCG) (Mihos 2015, Montes 2022) and has the ability to give information about the accretion history and evolutionary stage of galaxy clusters (Rudick et al 2006). However, observational and simulation-based approaches have been used to study ICL, which results potential systematic difference in the ICL classification (Rudick et al. 2011). Observations showed the transition between ICL and BCG show no clear break (Montes et al. 2021, Marini et al. 2022), which makes it challenging to distinguish them (Contini et al. 2014, Rudick et al. 2011). Surface brightness cut is one of the techniques used in observations to separate ICL from BCG, where simulations also agree that the method works perfectly at a surface brightness fainter than $\mu_V > 26.5$ mag arcsec^{-2} (Montes 2022). The differences on the separation techniques results difference on the measured ICL fractions (Rudick et al. 2011). However, in all of the techniques, the low surface brightness of the ICL is a common property (Rudick et al. 2011) and the trend on the growth of ICL with time is observed in simulations (Rudick et al. 2011, Contini et al. 2014, Jiménez-Teja & Dupke 2019, Montes 2022).

Data

Groups are created as nearly uniform isolated spherical primordial overdensity z=3 that first expand linearly, then turnaround, and finally undergo a completely no linear collapse. The initial overdensity value is chosen so that a homogeneous top-hat perturbation would collapse at z = 0 (see Solanes et al. 2016, Perea & Solanes 2016).

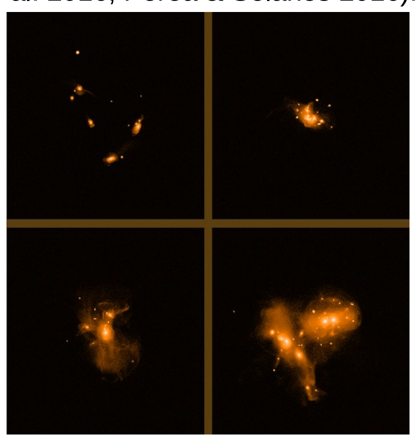
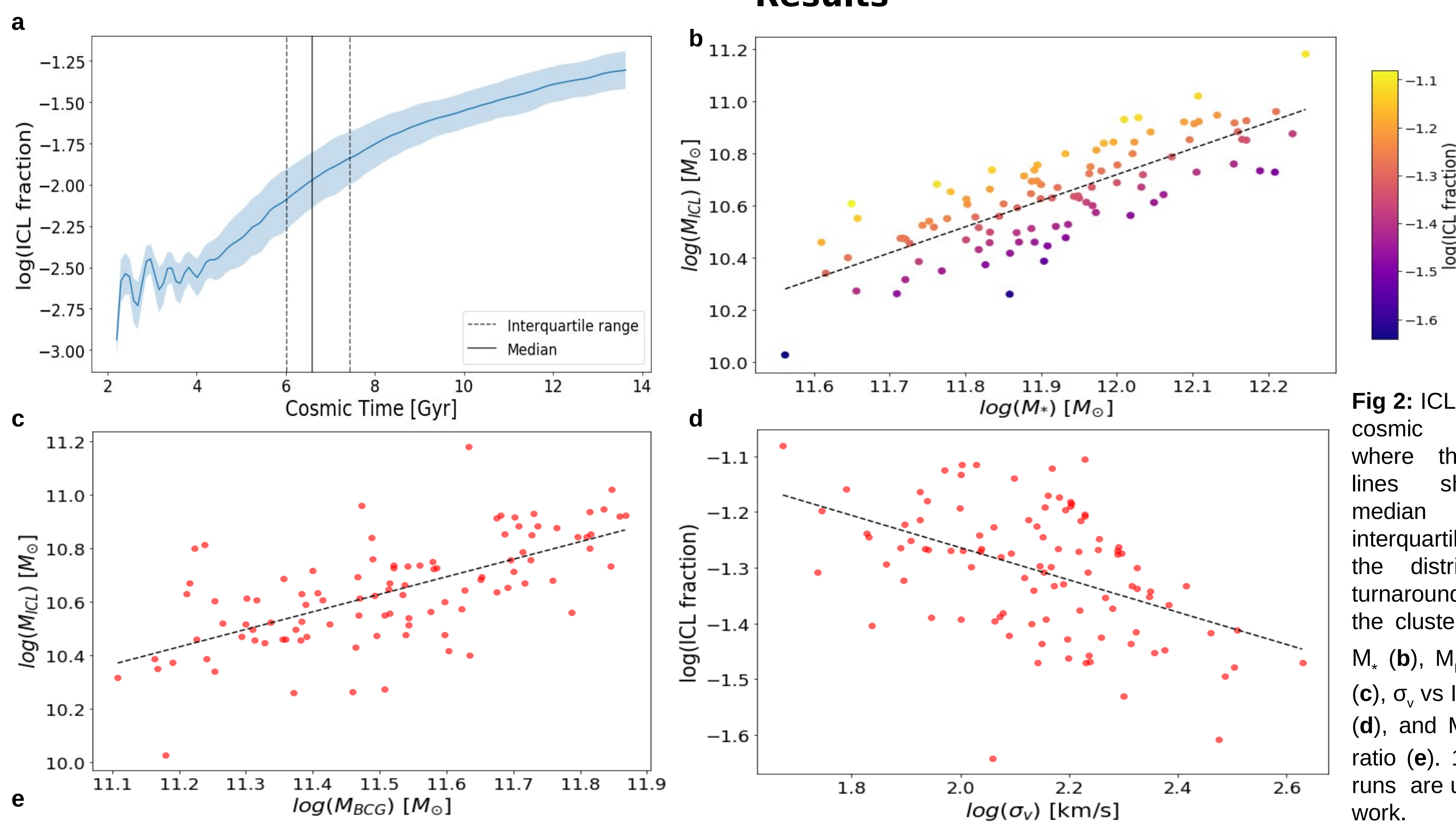


Fig 1: The image shows different galaxy clusters in our simulation. The top two images are clusters with low ICL fraction and the bottom two images are with high ICL fractions.

We have investigated the degree to which a series of parameters related to the mass, fraction and formation rate of ICL are correlated and how well a regression equation represents the association between them. These parameters, which are listed in Table 1 (see also Fig. 2), are: total mass of the system (M_{tot}), total stellar mass (M_*), mass to luminosity ratio (M/L), mass of ICL (M_{ICL}), mass of BCG (M_{BCG}), velocity dispersion (σ_v), core radius (R_{core}), ICL formation rate (ICLFR), and ICL fraction. Both the R_{core} and the σ_v are mass weighted and the ICLFR is obtained from the slope of the change in ICL fraction with time.

Results



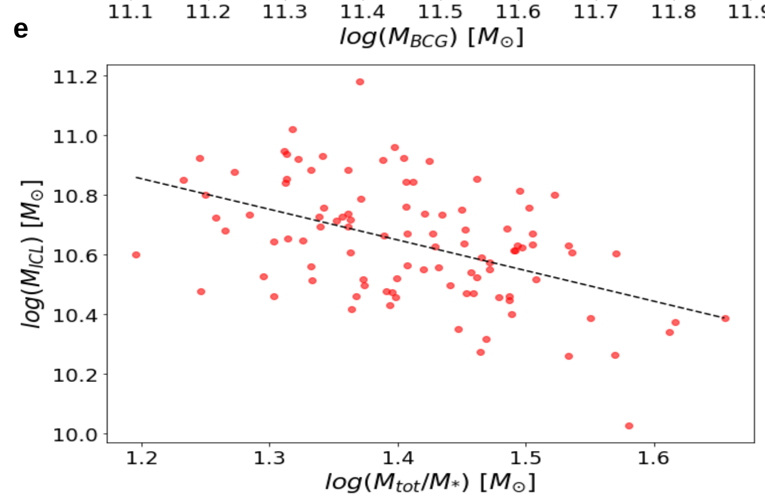


Fig 2: ICL fraction vs cosmic time (**a**) where the vertical lines show the median and interquartile range of the distribution of turnaround time of the clusters, M_{ICL} vs M_* (**b**), M_{ICL} vs M_{BCG} (**c**), σ_v vs ICL fraction (**d**), and M_{ICL} vs M/L ratio (**e**). 101 cluster runs are used in this work.

log(x)	log(y)	r	p
M_{tot}	M_{ICL}	0.58	1.0
M_*	M_{ICL}	0.8	1.0
M_{tot}/M_*	M_{ICL}	- 0.48	0.99
M_{BCG}	M_{ICL}	0.65	1.0
M_{ICL}	ICLFR	0.41	0.99
M_{ICL}	ICL fraction	0.61	1.0
M_{BCG}	ICLFR	0.32	0.99
M_{BCG}	ICL fraction	0.42	0.99
σ_v	ICLFR	- 0.4	0.99
σ_v	ICL fraction	- 0.47	0.99
R_{core}	ICL fraction	0.35	0.99
ICLFR	ICL fraction	0.78	1.0

Table1: Correlations between pairs of parameters: **r** – Pearson correlation coefficient, **p** – probability that the two parameters are correlated.

Conclusions

- The ICL begins to form in substantial amounts ~ 2 Gyr before turnaround and keeps growing steadily with cosmic time (decreasing redshift) until the end of the simulations (z = 0).
- The larger the initial stellar mass, the larger both the amount of ICL and mass of the BCG. However, while the mass of ICL produced grows linearly with M_*, the growth of M_{BCG} is only sublinear (the logarithmic slopes are 1.0 and 0.63, respectively). This behavior is maintained when fixing the total (virial) mass of the clusters, implying that the M/L ratio of these systems and M_{ICL} are negatively correlated.
- The efficiency of formation of ICL depend on the σ_v of the galaxies in the cluster. Low σ_v maximizes interaction in the group which increases the ICL formation. Therefore, the lower the σ_v the higher the ICL fraction.

References

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