

Thief Galaxy Groups: Signatures of Cluster Passage

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SAC XXI

Belgrade, 2026

Motivation and goals

- Cosmic Web - the interconnected network composed of voids and DM filaments at whose intersections reside galaxy clusters
- Galaxy clusters grow by constant accretion flow along DM filaments
- Hierarchical growth of structure $\Rightarrow$ individual galaxy evolution depends on the environment $\Rightarrow$ morphology-density relation (Dressler 1980a, 1980b)
- galaxy mergers, accretion, galaxy flybys, ram pressure stripping (RPS)
- cDs, jellyfish galaxies, compact elliptical galaxies (cEs), backsplash galaxies

Galaxy groups processed by a cluster

- We investigate how galaxy groups can be processed by a cluster using a cosmological simulation
- We study groups of galaxies that form in isolation, fall together inside a cluster and then escape the cluster
- We explore the possible effects of a cluster passage on those galaxy groups as well as on individual group members.

Stealing galaxies from galaxy clusters

Smole M., Micic M., Mitrasinovic A., 2025, PASA, 42, 86

- Illustris TNG300 cosmological simulation ($\sim 300\text{Mpc}$)³
- Groups with masses from $8 \times 10^{11} M_{\odot}$ to $7 \times 10^{13} M_{\odot}$
- Evolutionary path - we trace back the evolutionary tree of each galaxy within the group.
- Two sets:
 - ① **field groups** - evolved in isolation (32983 groups)
 - ② **cluster groups** - groups that were a part of a galaxy cluster at any time during their history (49 groups, $< 0.2\%$)
- **cluster groups**:
 - ① **thief groups** - groups that passed through a galaxy cluster and captured more galaxies from that cluster (23 cluster groups)
 - ② **non-thief groups** - groups that did not capture any new members (26 cluster groups)

Group compactness parameter

$$\langle d_w \rangle = \left\langle \frac{d_i \times M_i}{M_{\text{tot}}} \right\rangle. \quad (1)$$

mean distance between group members, weighted by the total group mass

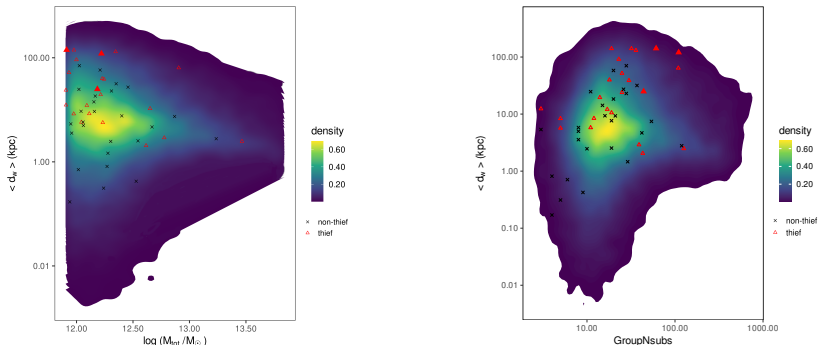


Figure: Galaxy compactness parameter as a function of the total group mass (left panel) and the total number of group members (right panel).

Table 1. p-values from statistical tests

		field vs cluster	field vs thief	field vs non-thief	thief vs non-thief
$M_{\text{tot}} - \langle d_w \rangle$	cramer	1.99×10^{-3}	0	0.91	4.00×10^{-3}
	npdeneqtest	0.02	2.22×10^{-16}	0.69	0.07
	peacock	1.91×10^{-3}	2.25×10^{-4}	0.57	0.14
$N_{\text{gal}} - \langle d_w \rangle$	cramer	0.03	1.99×10^{-3}	0.18	4.45×10^{-3}
	npdeneqtest	0.01	2.22×10^{-16}	0.43	0.06
	peacock	6.77×10^{-3}	3.35×10^{-3}	0.21	0.15

- Groups that go through a galaxy cluster and capture new galaxies from the cluster are less compact and have more members than other groups in the same mass range.
- The cluster passage itself does not influence the compactness of the group. Groups that enter a galaxy cluster as already virialized systems and do not accrete new galaxies follow the same distribution as the field groups

Thief groups

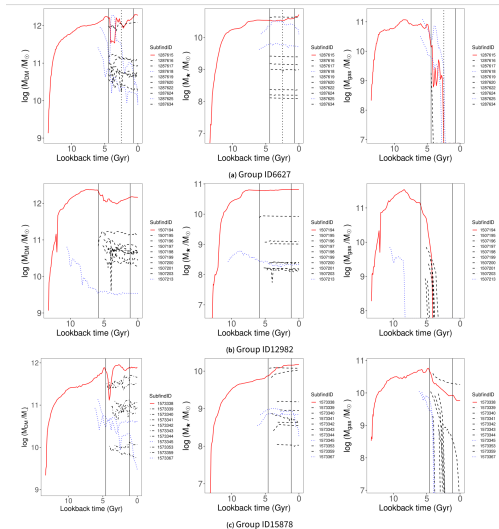


Figure: Total DM, stellar and gas mass of group members as a function of the lookback time.

Galaxy compactness in thief groups

- Does the cluster passage influence the compactness of galaxies in thief groups (Chilingarian and Zolotukhin 2015)?

- Galaxy compactness can be quantified using observationally determined criteria, such as Barro et al. (2013):

$$\Sigma_{1.5} \equiv \log \frac{M_{\star}}{(0.75 \cdot R_{0.5, \star})^{1.5}} \left[\frac{M_{\odot}}{\text{kpc}^{1.5}} \right] > 10.3.$$

- The most compact galaxy in our thief sample, SubfindID 1287618, has $\Sigma_{1.5} = 10$.

- mass-size relation

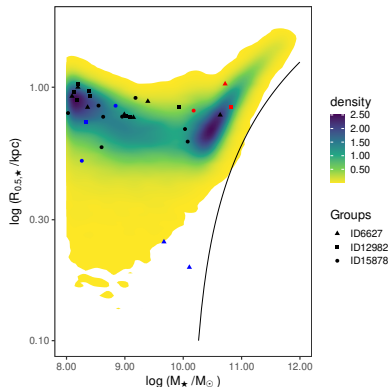


Figure: colour-coded distribution of field group galaxies at $z = 0$ in the mass-size plane.

Galaxy compactness in thief groups

- The compactness of satellite galaxies steeply increases as soon as galaxies become a part of the group.
- In the group phase galaxies already experience strong tidal stripping.
- New stars form at the core of the galaxy, stellar mass increases, and galaxies become more compact.
- By the time the host group merges with a cluster, both galaxies have already reached a high level of compactness. This supports the idea that cEs are formed by tidal interactions with the massive host galaxy (Deeley et al. 2023).
- Further cluster passage, as well as cluster merger, has only a slighter influence on the satellite galaxies' compactness parameter.

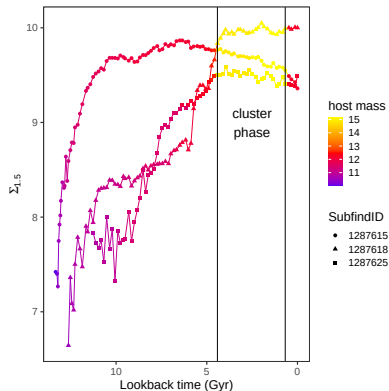


Figure: Evolution of $\Sigma_{1.5}$ in group ID6627 as a function of the lookback time. Circles represent the main galaxy, while triangles and squares represent satellite galaxies. Different colours indicate the total host halo mass in units $\log M_{\text{host}} / M_{\odot}$.

Cluster groups represent an example of rare objects ejected from a cluster environment → insights into how the environment influences both groups as gravitationally bound systems, but also individual galaxies.

① Group compactness:

- Thief groups are generally less compact and contain more members compared to field groups.
- Non-thief groups have the same properties as the field groups → the cluster passage itself does not influence the group compactness

② Individual galaxy compactness:

- Satellite galaxies become compact in the group phase before the cluster infall, as a result of tidal interactions with the massive host galaxy
- The compactness parameter of satellite galaxies does not change significantly in the cluster phase.

③ Future work: morphological transformations of galaxies within groups late-type to early-type

THANK YOU

References:



Dressler, A. 1980a

A catalog of morphological types in 55 rich clusters of galaxies.

ApJS 42, 565



Dressler, A. 1980b

Galaxy morphology in rich clusters: implications for the formation and evolution of galaxies

ApJ 236, 351



Chilingarian, I. and Zolotukhin, I. 2015

Isolated compact elliptical galaxies: Stellar systems that ran away.

Science 6233, 418

Barro, Guillermo, S. M. Faber, Pablo G. Pérez-González, David C. Koo, Christina C. Williams, Dale D. Kocevski, Jonathan R. Trump, et al. 2013. CANDELS: The Progenitors of Compact Quiescent Galaxies at $z \sim 2$. *Astrophysical Journal* 765, no. 2 (March): 104



Barro et al. (2013)

CANDELS: The Progenitors of Compact Quiescent Galaxies at $z \sim 2$.

ApJ 765, 104



Deeley et al. (2023)

The formation pathways of compact elliptical galaxies.

MNRAS 525, 1192

Orbits of thief groups

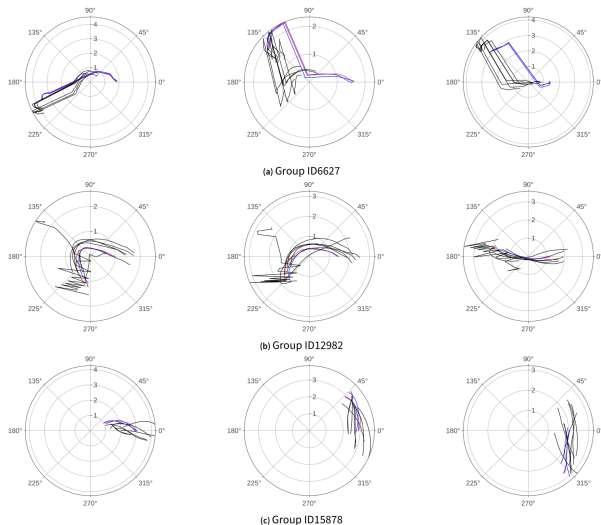


Figure 3. Orbits of each group member during the cluster phase. Panels represent 'x-y', 'x-z', and 'y-z' projections in polar coordinates, respectively. The same colour notation as in Figure 2 is used.

Gravitationally bound systems?

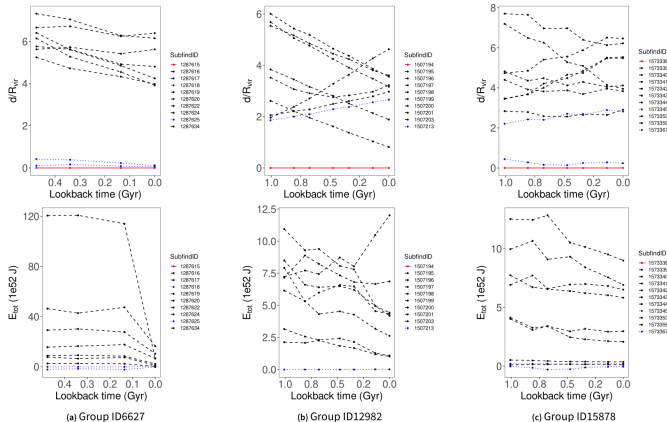


Figure 4. Relative distance (upper panels) and the total energy (lower panels) of group members as a function of lookback time. The same notation as in Figure 2 is used.