Intracluster Light Strengthens the Connection Between Stellar Mass and Dark Matter Mass in Galaxy Clusters

Highlights

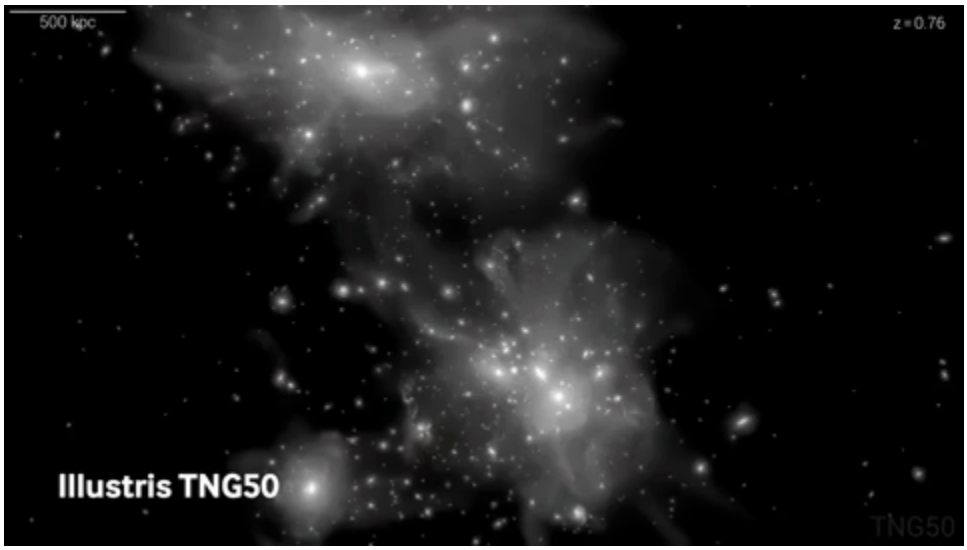
- By incorporating intracluster light (ICL) into the bright central galaxy (BCG) stellar mass, astrophysicists measure a stronger correlation between the BCG stellar mass and galaxy cluster halo mass.
- This finding reveals that the ICL's formation is tied to the growth of the BCG (through mergers and tidal stripping) as well as that of the cluster's dark matter halo.
- Using color, astrophysicists confirm that galaxy interactions at the outskirts of poorer galaxy clusters, like tidal stripping, can be the origin of recent ICL production.
- A high-quality sample of approximately 270 galaxy clusters was used to study ICL evolution with cosmic time.
- This analysis combines data from the Dark Energy Survey (DES), a large optical survey of nearly ⅛ of southern hemisphere sky in five filters, and the Atacama Cosmology Telescope (ACT), which observes in microwave from 5200 m on Atacama plateau. This study was led by an Astrophysicist from Shanghai Jiao Tong University, China.

Galaxy clusters are the largest gravitationally bound structures in the universe. Besides galaxies, clusters are made of hot gas only seen in X-ray, rogue stars that sum up a very faint halo of light known as intracluster light (ICL), and the invisible dark matter, which accounts for most of the cluster's mass. High quality observations by the Dark Energy Survey (DES) allow us to observe the ICL in hundreds of galaxy clusters. DES is a digital sky survey that was observed over 6 years with a super sensitive 570 Megapixel camera (DECam) installed on the Blanco 4-meters telescope in Chile. Observations from the Atacama Cosmology Telescope (ACT) allowed us to select a sample of galaxy clusters across the universe's recent history with a well-defined mass limit, avoiding bias on ICL evolution. ACT is a 6-meter telescope in Chile, capable of observing, in the microwave wavelengths, subtle signals of the interaction of cosmic microwave background radiation's interaction with the cluster's hot gas.

This article – led by Jesse Golden-Marx at Shanghai Jiao Tong University, China, Yuanyuan Zhang at Texas A&M University, USA, and Ricardo Ogando at Observatório Nacional, Brazil – analyzes a large, high-quality, well-defined sample of about 270 galaxy clusters covering a sizeable volume of the universe. This sample is used to see how the ICL evolves as a function of cluster radius and distance from the Earth. Previous studies dealt with only a few dozen clusters. Using the DES and ACT data, this work aims to improve our understanding of galaxy cluster mass, which consists mostly of the mysterious dark matter, using the ICL, the dim light

from rogue stars floating between galaxies in a cluster that surrounds the bright central galaxy (BCG). The researchers found that ICL mass did not evolve in the recent history of the universe between 2.5 and 8 billion years ago. However, accounting for the mass within the ICL in their measurement of the BCG's stellar mass yields a stronger connection with the underlying dark matter halo mass. This result suggests that the ICL's formation and growth is tied to the growth of both the BCG and the underlying dark matter halo.

Moreover, observations suggest that ICL stars are removed from galaxies in clusters through interactions, such as galaxy disruption, tidal stripping, or even mergers. The animation below shows some of these processes happening in galaxy clusters in the Illustris TNG50 simulation, where one can see trails of stars scattered during interactions and filling the space between galaxies, especially around the BCG. When looking at the ICL colors, we see that the ICL is bluer than the BCG's core. However, only the poorest clusters in the sample presented some color evolution in their outskirts, with bluer light (young population) appearing at earlier lookback times. This color gradient and variation hints that tidal stripping can be more important than mergers for ICL production, as the latter would destroy this color gradient.



This movie from the simulation Illustris TNG50 by Dylan Nelson illustrates galaxies interactions inside a galaxy cluster. Credit:
[APOD: 2019 February 26 - Simulation TNG50: A Galaxy Cluster Forms]

According to Jesse Golden-Marx, "This is one of the largest samples of clusters with ICL measurements, which allowed us to incorporate the ICL into the Stellar Mass - Halo Mass relation and analyze the ICL's color as a population. As we look to expand on these results with DES data and look to the future with the Vera Rubin Observatory, it's exciting to think about the role the ICL and diffuse light will continue to play in shaping our understanding of BCG growth."

Understanding how galaxies form and evolve, especially within environments like galaxy clusters – cornerstones of the cosmic web – is of paramount importance to trace our origins. This study opens up several future possibilities for how to improve the understanding of BCG growth and the role of the ICL, including understanding the cosmic evolution of the colors and mass of the ICL using the entire DES dataset (hence including smaller clusters than the ones in the DES+ACT sample).

Contacts

Jesse Golden-Marx
Shanghai Jiao Tong University, China
Email: jessegm@sjtu.edu.cn

Ricardo Ogando
Observatório Nacional, Brazil
Email: ogando@on.br

Links

- Characterising the Intracluster Light over the Redshift Range 0.2 < z < 0.8 in the DES-ACT Overlap
- APOD: 2019 February 26 - Simulation TNG50: A Galaxy Cluster Forms
- Illustris TNG50 GIF