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Netting Space Jellyfishes in the Hubble Telescope Data Archive

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Project Summary

Galaxy clusters are the gravitationally bound structure of hundreds or even thousands of galaxies. They are the largest virialized structure in the Universe. Most baryons (or ordinary matter) in galaxy clusters are in the hot intracluster medium (ICM) with temperatures of $10^7 - 10^8$ K. Together with cluster galaxies, they form the cluster ecosystem. Cluster galaxies soar through the ICM and the interaction with the ICM plays a vital role in galaxy evolution, through ram pressure stripping of the galactic cold gas. As the cold interstellar medium (ISM) is depleted in the stripping process, the galactic star formation (SF) will eventually be shut down and blue disk galaxies can turn into red galaxies. Thus, stripping is an important process in galaxy evolution. Observational evidence of stripping in cluster galaxies has only started to emerge in the last 12 years and is growing fast.

Despite the early general wisdom that the stripped cold gas will simply mix with the hot ICM and be heated, it is now known that some fraction of the stripped ISM can turn into stars in the intracluster space, with PI's pioneering work played a key role. Many examples of cluster galaxies with SF trails (or "jellyfish" galaxies) have been discovered. It is now believed that SF in the ISM stripped by ram pressure is a widespread phenomenon in rich clusters. While there are some ongoing multi-wavelength projects to have detailed analysis on individual "jellyfish" galaxies, such analysis is only possible for nearby galaxies. A sample only with nearby systems is volume limited, missing very luminous star clusters seen at the downstreams of some galaxies at redshift beyond 0.2 (or far away from us). Optical imaging remains as the most efficient way to find "jellyfish" galaxies. Young star clusters in tails provide **an important piece of the puzzle as they reveal the recent cooling products of the stripped gas.** With the large amount of the Hubble Space Telescope (*HST*) archive data on galaxy clusters (from e.g., Frontier fields, deep data for gravitational lensing and background supernovae), we propose a comprehensive and quantitative search and study of the "jellyfish" galaxies in massive galaxy clusters. We emphasize that such kind of large sample, quantitative studies has **never been done before** and will provide important samples to have a un-biased view of the population.

Dr. Sun's group has developed a simple but effective method to select "jellyfish" galaxies from the optical images. This has been applied by a past undergraduate student on the *HST* data of one galaxy cluster and the results are very promising. With the initial success, we propose to apply the method to a large *HST* sample of galaxy clusters.

Our science goals are:
1) Creating an unprecedentedly large, homogeneously selected sample of "jellyfish" galaxies.

Once such a large sample is made, we can examine relations between "jellyfish" galaxies and various cluster properties, e.g., distance from the cluster center, local ICM pressure, cluster richness and the cluster mass. We will also compare the properties of the observed "jellyfish" galaxies (e.g., the mass, the dimension and appearance of SF tails) with those from simulations. The fraction of "jellyfish" galaxies is another important question, giving us constraints on the triggering criteria and timescale of "jellyfish" features.
2) The properties of the discovered young star cluster associations behind "jellyfish" galaxies will also be constrained with the existing *HST* data, especially for systems with multi-band coverage (e.g., CLASH + RELICS + Frontier clusters).

Student Prerequisites

The successful applicant should have a good academic record (GPA > 3.3) and have finished introductory physics classes. The successful applicant should also have experience with computer programming (with e.g., python, R, C, Fortran) and scripting (with e.g., python, perl, shell).

Student Duties

The RCEU student will work on the *HST* data of galaxy clusters. We will start with reduced *HST* data provided by the *HST* data archive so there is no need to learn *HST* data analysis and calibration. The student will proceed the research with the following steps: 1) run SExtractor on *HST* images to create source tables, with output on positions, flux and size. 2) select only bright galaxies that are known to be in the cluster. 3) look for source over-density within 100 kpc of these cluster galaxies. In our early study, we divide the 100 kpc radius circle (with the galaxy masked) into 12 sectors, each with 30 deg wide. We look for over-density of SExtractor sources within our flux range for tail star clusters, at 1-2 adjacent sectors. The student will write a python script to read the source catalog from SExtractor to do the selection. 4) after the student successfully tries the script on one galaxy cluster, we plan to extend the work to about 50 clusters to compile a large sample of "jellyfish" galaxies. Interesting galaxies will be followed up by Dr. Sun's group with e.g., *HST* proposals (that would bring research grants to the UAH), ground spectroscopic observations. The results by the student will play an important role in our future proposals and papers on "jellyfish" galaxies. The student will be included in any publications with the sample. The student is also expected to present a poster on the project at a regional conference.

Mentor Supervision and Interaction

The mentor (Dr. Sun) has a large research group in the Physics department, with three postdocs (Dr. Liu, Dr. Ge and Dr. Chen) and five graduate students. Both the mentor and his postdocs/graduate students will interact with the RCEU student in regular basis and provide close tutoring. Dr. Sun's senior graduate student, Will Waldron, is an expert on *HST* data and python programming and will also interact with the student regularly. At the initial stage of the project, the student and mentor will meet about 2 hours per day to start the project. After the initial stage, the student will work more independently, consulting with the mentor and other group members when needed, also with weekly meetings with the mentor. Office space for the student will be provided in the Optics building. Laptop and workstation access can also be provided.

Prior Awardees

Dr. Sun supported one RCEU student in 2018, Cody A. McCammon, on the research project "Super-Massive Black Holes and Their Hot Gas Environment". Mr. McCammon wrote scripts to analyze *Chandra* data of X-ray cool cores of some galaxy groups. He was able to derive some temperature profiles and obtain some interesting results. Mr. McCammon has presented the final poster of the work and we plan to have him present the work in a future regional conference. With this project, Mr. McCammon has gained experience on Linux system and commands, programming, scientific methods and presentation. He has also gained a deeper understanding of the evolution of supermassive black holes, galaxies and the general scientific research.