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Studying the Most Massive Galaxies in the Universe

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Project Description

Galaxies are the building blocks of our Universe. While most mass in galaxies is in dark matter, detections and studies of galaxies still rely on baryons as we still cannot detect dark matter directly — it is still essential to trace mass with light. Galaxies come with different size and mass. The hierarchical formation of the cosmic structure predicts that the most massive galaxies form the latest, thus offering important clues on galaxy formation. The most massive galaxies typically reside in dense environment like galaxy clusters. Galaxy clusters are the gravitationally bound structure of hundreds or even thousands of galaxies. They are the largest virialized structure in the Universe. First-ranked galaxies in clusters, also referred to as brightest cluster galaxies (BCGs), are the most luminous and massive galaxies in the Universe, being up to 100 times brighter than our Milky Way. Many BCGs are also characterised by an extended "envelopes" or halo over hundreds of kiloparsecs. BCGs also likely host the most massive supermassive black holes (SMBHs) in the universe, which were formed accompanying the formation of BCGs and can inject a large amount of energy into the surroundings to affect BCG evolution.

The most massive galaxies in the Universe, as BCGs (or not?), are great objects to study galaxy evolution. As each of them is the product of many mergers over its life time (to follow the so-called merger tree of the galaxy), analysis of the morphology, stellar population and the surrounding galaxy population offers hints of the merger history. The accompanied growth of the central SMBH would leave imprint on the properties of the galaxy and its surrounding medium. While there have been many studies on BCGs in the existing samples of galaxy clusters, there has been **no** studies focused on samples of most massive galaxies selected from their luminosity or velocity dispersion within, which is the focus of this RCEU proposal.

This project will focus on the data from the Sloan Digital Sky Survey (SDSS). SDSS is a large imaging and spectroscopic survey with a dedicated 2.5-m wide-field telescope. It has surveyed over 1/3 of the whole sky and taken spectra of over 2 millions of galaxies. We will combine the imaging and spectroscopic data from SDSS to select the most luminous galaxies, by their luminosity and velocity dispersion of their stars.

Our science goals are: 1) Compile a large, homogeneously selected sample of the most massive galaxies at three redshift ranges, $z < 0.1$, $z = 0.1 - 0.2$ and $z = 0.2 - 0.3$. Selection will be done from both the total luminosity and the velocity dispersion. Contaminations from each method will be examined, by examining near-infrared data from 2MASS and *WISE* and additional spectroscopic data in the archive. What are the galaxy luminosity and velocity dispersion functions at the high-mass ends at these z? How much overlap are the samples from these two selections? 2) Study the properties of galaxies in these samples. Are they always in galaxy clusters? Are there isolated galaxies in these samples? What is the fraction of galaxies with multiple components indicative of recent major mergers? We will also examine the activities of their central SMBH with the X-ray and radio data. We emphasize that such a large sample provides opportunities of follow-up studies in multi-wavelength.

Student Duties, Contributions, and Outcomes

The RCEU student is expected to work 320 - 340 hours in total for this RCEU project. The RCEU student will proceed the research with the following steps: 1) Run SQL searches on the SDSS data server to look for the most luminous galaxies among galaxies with spectroscopic redshifts. This step will involve several iterations as the initial search may very likely result in contamination sources from e.g., artifact. We expect to generate samples of top 100 most massive galaxies at three redshift ranges shown above. 2) Study the 2MASS and *WISE* near-infrared data to verify the high luminosities of the resulting sample. 3) Study the environment of these galaxies. Are they in known galaxy clusters and groups? 4) Examine the multi-wavelength properties of these galaxies from radio, infrared to X-rays. Are their SMBHs active?

The samples generated from the work of the RCEU student will be a valuable sample for follow-up studies. Dr. Sun's group will propose follow-up projects with *Chandra* and *HST* telescopes, both came with research grants. The results by the student will play an important role in our future proposals and papers. 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. Upon the finish of the project, the student will have real experience of astronomical research, gain a deeper understanding of galaxies and SMBHs, obtain the programming skill important for the future career, and develop problem solving skills both analytically and numerically.

Student Selection Criteria

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, or C) and scripting (with e.g., python, or shell).

Faculty/Research Staff Mentorship

The mentor (Dr. Sun) has a large research group in the Physics department, with three postdocs (Dr. Liu, Dr. Ge and Dr. Luo) and four 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 postdoc, Chong Ge, is familiar with SQL and SDSS data and will interact with the student regularly. Dr. Sun's other postdocs and graduate students are all experienced programmers and will help to train the student in regular basis. At the initial stage of the project, the student and the mentor will meet about 2 hours per day to start the project. Early start in the spring semester is also encouraged. 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.