1-1-2020

Hunting for Ultra Diffuse Galaxies in the Hubble Space Telescope Data Archive

Ming Sun
University of Alabama in Huntsville

Hunting for Ultra Diffuse Galaxies in the Hubble Space Telescope Data Archive

Faculty Mentor

Dr. Ming Sun
Associate Professor
Department of Physics and Astronomy
Optics Building 214
phone: 256-824-2126
email: ms0071@uah.edu

Proposal Identifier: RCEU20-PH-MS-01

Project Description

Galaxies are island universes where stars find home. Galaxies reside in dark matter halos that have already collapsed under their own gravity to be decoupled from the expansion of the Universe. While most mass in galaxies is in dark matter, detections and studies of galaxies focus on their baryons as we still cannot detect dark matter directly. Thus, using light to trace mass remains important to study cosmology and cosmic structure formation. The cosmological simulations have predicted the halo mass function well. However, the low-luminosity end of the galaxy luminosity function remains uncertain, limited by the capabilities of the current optical telescopes. A recent breakthrough, with a custom-made telescope, is the discovery of a new type of galaxies, ultradiffuse galaxies (UDGs), in 2015 (the initial discovery paper has been cited for over 200 times and there have been over 150 papers on UDGs since 2015).

UDGs can be well defined in the plot of the central surface brightness vs. the effective radius (or the half-light radius) for galaxies. Large galaxies like our Milky Way and Andromeda have large effective radii and high central surface brightness, while typical dwarf galaxies (like large and small magellanic clouds) have lower central surface brightness and smaller effective radii. UDGs, on the other hand, have effective radii comparable to our Milky Way but the central surface brightness as low as those found in diffuse dwarf galaxies — they are faint but large! Thousands of UDGs have been discovered in nearby galaxy clusters and groups. UDG has attracted a lot of attention as they are potentially dark-matter-dominated systems with few baryons. Thus, they are important objects to study dark matter. Their formation and evolution also offer important clues on important processes on galaxy evolution, e.g., stellar feedback and hierarchical merger history. UDGs also provide an important test for the theory of Modified Newtonian dynamics.

UDGs were initially discovered by the Dragonfly Telephoto Array specially designed to study low-surface-brightness objects. The Dragonfly telescope has the advantage of low scattering light and large field of view. However, its angular resolution is very poor so follow-up observations are always required. On the other hand, *Hubble* space telescope (*HST*) provides the sharpest optical view to detect/study UDGs, especially since the *HST* archive has data of over two hundreds of galaxy clusters after 29 years of operation (*HST* was launched in 1990). Indeed, Dr. Sun has detected over 10 new candidates of UDGs from a pilot work on just 5 *HST* observations of nearby galaxy clusters, inspired by a serendipitous discovery on his own *HST* data. With the initial success, we propose to study UDGs with the very rich *HST* archive.

Our science goals are: 1) creating an unprecedentedly large, homogeneously selected sample of UDGs from the archival *HST* data. Once such a large sample is made, we can study the number density of UDGs, their population properties and their relation with the host galaxy clusters. We will also compare their properties with those from simulations. 2) studying the multi-wavelength properties of UDGs in the sample to understand their formation mechanism. Follow-up spectroscopic observations will also be proposed to obtain their redshifts and metallicities.

Student Duties, Contributions, and Outcomes

The RCEU student is expected to work 320 - 340 hours in total for this RCEU project. The student will work on the *HST* data of nearby galaxy clusters. We will start with reduced *HST* data provided by the *HST* data archive and Dr. Sun's graduate students 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 the *HST* images to create source tables, with output on positions, size and flux. 2) tune the SExtractor parameters to make sure UDGs are detected. 3) plot the surface brightness — size diagram to select UDGs. 4) make radial profiles of UDGs in all available *HST* bands and derive the global properties of the UDGs, e.g., total luminosity, half-light radius and light profile slope etc. 5) repeat the work for about 100 - 200 *HST* fields. 6) based on the total sky area covered by *HST*, estimate the frequency of UDGs in galaxy clusters. 7) examine the multi-wavelength properties of UDGs. Interesting UDGs will be followed up by Dr. Sun's group with more proposals (that would likely bring research grants to the UAH). The results by the student will play an important role in our future proposals and papers on UDGs. 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 galaxy evolution, 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 senior graduate students, Will Waldron and Sunil Laudari, are experts on *HST* data analysis and python programming and will also interact with the student regularly. Dr. Sun's postdocs 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.