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Using Neural Network to Search for Isolated Hα Clouds in the Virgo Cluster

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RCEU 2022 Project Proposal

Project Title

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I. Project Description

Galaxies are island universes where stars find home. Galaxies are strongly clustered with the densest parts as galaxy clusters which are composed of thousands of galaxies, gravitationally bound together with a typical total mass of 10^{14} - 10^{15} $M_{\odot}$. Most baryons (or regular matter) in galaxy clusters are in the hot (T ~ 10^{7} - 10^{8} K) intracluster medium (ICM). Cluster galaxies soar through the ICM and the interaction with the ICM plays a vital role in galaxy evolution, mainly through ram pressure stripping (RPS). RPS can remove cold gas from galaxy and recent observations suggest those stripped cold galactic gas can survive in the hot ICM for a long time.

Among all gaseous tracers, Hα remains as the most efficient one for the high sensitivity of the current optical telescopes. The Hα emission traces warm (T ~ 10^{4} K), ionized gas. Recently we were granted a large program with the 3.5m Canada-France-Hawaii Telescope telescope to produce an Hα survey of the Virgo cluster, A Virgo Environmental Survey Tracing Ionised Gas Emission (**VESTIGE**) (PI: Boselli, Co-I: Sun and others). The Virgo cluster is the closest galaxy cluster and this new survey, taking advantage of the 1 deg^2 field-of-view of the MegaCam, will provide the state-of-art data to study RPS with the warm, ionized gas on Virgo cluster galaxies. Our team also has multi-wavelength supporting data for the Virgo cluster.

In this RCEU project, we will use various neural network methods (e.g., mask R-CNN and capsule neural network) to search for isolated Hα clouds away from galaxies in the VESTIGE data automatically. We have visually examined the data and selected a sample of isolated Hα clouds as the potential training set. Optical spectroscopic observations have also been planned to validate the training set. This machine learning approach is important to generate a complete, objective and unbiased sample of isolated Hα clouds in the VESTIGE data and the resulting code can also be applied to other similar research involving large imaging survey data. Our science goals are: 1) test different neural network methods to select isolated clouds, guided by the training set. We will also study the properties of the clouds, e.g., size, total luminosity, distance to nearby galaxies etc. Optical artifacts like ghosts, scattered lights and flat field residuals should be filtered by the neural network efficiently. 2) we will also test unsupervised learning methods, e.g., classification based on the properties of detected features, to select isolated clouds. Results from both methods will be compared. In the end, a sample of isolated Hα clouds will be constructed and will be followed by optical spectroscopic data and other multi-wavelength observations to understand their nature.

II. Student Duties, Contributions, and Outcomes

a. Specific Student Duties

The RCEU student is expected to work 320 - 340 hours in total for this RCEU project. The student is expected to have background on python programming and will work on python codes for the project. The student will proceed the research with the following steps:

1) get familiar with the VESTIGE data and different type of features on the net Hα images.
2) write codes of various neural network methods (e.g., mask R-CNN and capsule neural network) to search for isolated Hα clouds away from galaxies in the VESTIGE data, with the training data provided.
3) compare results from different methods and finalize the combined sample
4) examine the multi-wavelength properties of the selected Hα clouds with the archival data.

b. Tangible Contributions by the Student to the Project (10% of Review)
Finish python codes of various neural network methods to search for isolated Hα clouds and also examine the results to debug codes.

c. Specific Outcomes Provided by the Project to the Student (30% of Review)
Interesting Hα clouds will be followed up by Dr. Sun's group with more proposals (that would likely bring research grants to the UAH). The codes and selected sample by the student will play an important role in our future proposals and papers on isolated cold/warm clouds in galaxy clusters. 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.

III. Student Selection Criteria

The successful applicant should have a good academic record (GPA > 3.4) and have finished introductory math & physics classes. The successful applicant should also have experience with python. Previous experience with data mining and machine learning is also preferred.

IV. Project Mentorship *(30% of Review)*

The mentor (Dr. Sun) has a large research group in the Department of Physics and Astronomy, with two postdocs and three 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 optical 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.