1-1-2022

Mining the Data Cubes in Sub-mm and Optical Astronomy

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RCEU 2022 Project Proposal

Project Title

Mining the data cubes in sub-mm and optical astronomy

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Proposal ID RCEU22-PH-MS-02

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I. Project Description

We often say "a picture is worth a thousand words". In Astronomy, we also say "a spectrum is worth a thousand pictures". Nowadays with the advance of observational technology, we can further say "a data cube is worth a thousand spectra". Data cubes from spatial spectroscopy have become more and more common in Astronomy, from radio, sub-mm, IR, optical to X-rays. Data cubes provide spectroscopic information on every pixel of a picture. Two world-leading telescope/instrument combo to produce data cubes with a high spectral resolution are *ALMA* in sub-mm and *VLT*/*MUSE* in optical. The rich amount of information in data cubes has also brought a lot of challenge on data analysis and visualization, as source detection becomes a three-dimensional problem and kinematics often needs to be studied together with morphology.

We are recently granted a large *ALMA* program to observe 28 galaxies and their stripped tails to study galaxy evolution (one of the only five large programs on galaxies with *ALMA* ever). We have also obtained some *VLT*/*MUSE* data for these galaxies. Dr. Sun is a co-PI for both projects. These data will produce data cubes in sub-mm and optical, containing a large amount of information on the physical properties of these galaxies and their tails. In this RCEU project, we will use various software to explore reduced data cubes from these observations. The software includes jdaviz, CARTA, lsdcat and Clumpfind.

Our science goals are:
1) run source detection in the three-dimensional cubes and make the final catalog of the detected sources to summarize their properties.
2) explore the best way of visualization to showcase the data cubes for publications and presentations.
3) compare the sources detected in *ALMA* and *MUSE* and compare their kinematics and other properties.

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 mainly work on python codes for the project. The student will proceed the research with the following steps:
1) get familiar with the ALMA and MUSE data cubes.
2) use several different software to explore data cubes and produce ideal visualization.
3) run source detection in the three-dimensional cubes and make the final catalog of the detected sources.
4) compare the sources detected in *ALMA* and *MUSE.*

b. Tangible Contributions by the Student to the Project *(10% of Review)*

Learn how to use various software to explore the data cubes and find the best combination, which includes coding with python. Generate source catalog from the source detection tool.

c. Specific Outcomes Provided by the Project to the Student *(30% of Review)*

The catalog generated by the student will be one of the key results of both projects. The conclusion from the visualization part of the project will provide useful guidelines for presentations and paper writing of our projects. The student will be included in any publications with the results contributed by the student. 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, 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 computer programming with python.

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 postdoc, Rongxin Luo, is an expert on optical data cubes and python programming and will also interact with the student regularly. 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.