Upsilon Lab *Fall 2019 Quarterly Report*

an Official UCLA Physics & Astronomy Department Sponsored Organization

Prepared by Emma Peavler, President & Alexander Tolstov, President

"A lab for undergraduates, by undergraduates."

Mission

The mission of Upsilon Lab is to provide undergraduate students in the UCLA Physics & Astronomy department the opportunity to learn valuable skills to succeed in their future endeavors, whether in research, engineering, or other fields.

Quarter Highlights

- Seven active projects with thirty-one active members. Read about their progress on **pages 4-10**.
- All projects will continue into Winter 2020, along with one new project. Interested in applying? Read more on **page 10**.
- We received a small grant from the Physics & Astronomy Department for our in-house projects.
- We expect to continue adding new members, aiming to include approximately 10% of the Physics and Astronomy Department students
- Contact us through our website! **upsilonlab.org**

Fall 2019 Summary

Upsilon Lab entered its third year at UCLA under the leadership of **Emma Peavler** and **Alexander Tolstov**.

There were a total of seven new and continuing projects consisting of thirty-one undergaduate members and lead by ten outstanding managers. Upsilon Lab also plans on establishing two new projects for the Winter 2020 quarter.

This quarter's active projects and managers are listed below. More information is included later in the report, on the respective project pages.

Active Projects

Advisory Board

The 2019-2020 Advisory Board is composed of two Department professors:

Prof. David Saltzberg, Chair

Prof. Chris Regan

We would like to profusely thank the Advisory Board for their help and advice throughout the quarter, and their continued support throughout the quarter.

Raspberry Pi for High-Altitude Balloon Applications

In-House Project in collaboration with the Bruin Spacecraft Group

Managed by Trey Knudsen **Contact: 39knudson05@gmail.com**

Project Description

This project will have a team utilize a Raspberry Pi micro-computer in order to control a high-altitude balloon (HAB). HABs are used primarily to collect measurements of the atmosphere at varying altitudes, including near-space! This can help study the weather and climate. Modern balloons generally contain electronic equipment such as radio transmitters, cameras, or satellite navigation systems. This project will focus on developing software that can collect data from an internal measurement unit (IMU) and creating real-time methods to analyze the data. **This project is a collaboration effort with the Bruin Spacecraft Group.**

Quarter Project Highlights

This quarter we analyzed atmospheric behavior as a function of temperature, pressure, and humidity in hopes of understanding both quantitatively and qualitatively how to characterize the atmosphere through possible measurements in a high-altitude balloon.

We derived the theoretical Barometric formula and characterized how we might make an experimentally determined equation of height vs. pressure as a more accurate alternative. The group also studied how stability is characterized in the atmosphere and analyzed it through temperature and potential temperature gradients. We are beginning to learn python to determine how to analyze the datasets that might correspond to measurements we will take.

Members of the group have been placed in different teams within the Bruin Spacecraft Group. These teams have learned software, mechanical, electrical, and communication techniques which correspond to high altitude balloon launches. The hope is that we can carry out our own launch by the end of the year.

Quarter Membership Roster

Swetha Sankur

Lorraine Nicholson

Rishi Acharya

Emir Izat

Waves and Waveguides: From Optics to Oceans

In-House

Managed by Jared Rivera **Contact: jaredrivera2314@gmail.com**

Project Description

Wave motion is pervasive in Physics and Astronomy, so being comfortable with the phenomena as well as its mathematical description is necessary for meaningful understanding of many physical processes. In this project we will investigate multiple types of waves in free space as well as in boundary-condition-enforced geometries (waveguides) through analytic math, numerical solutions, and simulations. We'll look at applications from the theory of wave optics to practical aspects of hydrology.

Quarter Project Highlights

This quarter started with forming the team and deciding when to meet regularly, which we did by the end of week 2. We then spent two weeks working on introductory programming tutorials with Python, focusing on skills useful for physical simulation. We then had several meetings on best simulation practices as well as project workflow. These covered topics such as numerical integration schemes, discretization, and efficient use of computational resources. This new knowledge was then put to the test when each member wrote a simulation of the classic projectile motion problem and compared it to the analytic result.

We then moved on to doing larger-scale individual projects that required more research. Each member developed their project plan and we've now seen simulations ranging from ocean wave energy harvesting to thin-film interference. These projects will help the members develop the skills needed to work on the main group project, which we've begun the architecture for. The project will be working on a software to simulate and animate a wave that has user-defined boundary interaction properties (reflectivity, transmissivity, loss).

Quarter Membership Roster

Cole Lorch

Katelyn Olson

Veronica Guo

Jagrit Digani

Ruiyao Liu

Modeling Quantum Systems With Machine Learning (Advanced)

In-House

Managed by Joshua Wong **Contact: jolwong@ucla.edu**

Project Description

Electrons are all over the place, and they're complicated! If only we could somehow model their wavefunctions... but with so many in a given molecule, that's practically impossible! I wonder, is there an easier way to model a complicated wavefunction...? Yes! We can use machine learning to do this!

Quarter Project Highlights

Team members completed an analytical investigation of particle motion in the presence of electromagnetic fields with application in cyclotron particle accelerators; generated Python programs involving control flow, class/function definitions, and 2D/3D plotting in the context of cyclotron accelerators; and implemented Runge-Kutta 4^{th} order and Euler approximations for particle tracking from Lorentz Force. The team will continue to expand on the simulation over the course of the academic year, adding features including simulation of multiparticle systems and position-dependent magnetic fields.

Quarter Membership Roster

Zooey Nguyen

Casey Mordini-Bluhm

Daniel Levi-Minzi

Modeling Quantum Systems With Machine Learning (Novice)

In-House

Managed by Zooey Nguyen and Daniel Levi-Minzi
Contacts: zooeyn@ucla.edu & dleviminzi@gmail.com

Project Description

Electrons are all over the place, and they're complicated! If only we could somehow model their wavefunctions... but with so many in a given molecule, that's practically impossible! I wonder, is there an easier way to model a complicated wavefunction...? Yes! We can use machine learning to do this! The novice group is learning the programming skills necessary to join with the advanced group.

Quarter Project Highlights

The novice group for the machine learning lab went over the fundamental math and theory behind machine learning. We used Andrew Ng's course on machine learning as the basis for the core lessons and then expanded upon the curriculum in other lessons. Topics covered include regression, gradient descent, regularisation, forward-feed neural network implementation, bias-variance, conventions for notation, complexity, and handling various dataset distributions. To complement the teaching components, we assigned Python homework to familiarise the group with the programming they'd be doing later in the advanced group.

Quarter Membership Roster

Hiya Gupta

Caroline von Raesfeld

Rishabh Singh

Atharva Kulkarni

Computational Methods for Physics

In-House

Managed by Suyash Kumar **Contact: suyashsep12@gmail.com**

Project Description

The project's current focus is to deliver central programming skills required to make progress in theoretical as well as experimental avenues of Physics. Two essential skills that come to mind are the ability to develop simulations for various physical phenomena and apply tools of machine learning to analysis of experimental data. Possessing these skills in ones' arsenal enables the Physics major to become equally profitable to research as well as industry.

Quarter Project Highlights

In Fall 2019, the major focus of the project was to practice developing simulations for oscillatory and wave phenomena as well as particle collisions. Both 2D and 3D simulations were explored for the former avenue, while progress in the particle collisions arena was only made up to 1D collisions (due to encountering mathematical complexities somewhat beyond the current knowledge of team members). Discussion of algorithms and data structures in computer science was simultaneously conducted to lay groundwork for machine learning ideas to be pursued in the coming quarters.

Quarter Membership Roster

Max Kroft

Sanchit Bawri

Parth Bhatnagar

Shruti Iyer

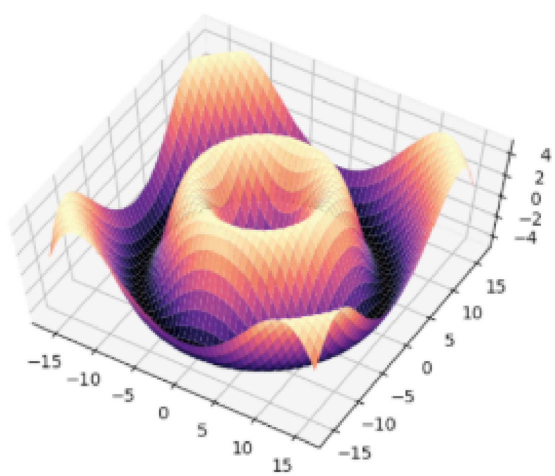

Figure: Still from simulation of radially propagating circular waves of the form $z(r,t) = A\sin(kr - \omega t + \phi)$, where $r = \sqrt{x^2 + y^2}$.

Decoding Brain Signals with Deep Learning

In-House

Managed by William Zhu **Contact: williamzhu@ucla.edu**

Project Description

Functional Magnetic Resonance Imaging (fMRI) is an imaging technique used to map neural activity in the brain by measuring blood flow. Studies have shown correlations between the visual stimuli presented to a subject and the sites of neural activity in a subject's brain. The goal of this project is to implement and train a neural network that could predict what is in a subject's visual field given fMRI data of neural activity.

Quarter Project Highlights

This quarter, our main objective was to equip project members with the necessary programming skills and to work on data preparation for the actual research starting next quarter. We had two separate groups this quarter: an introductory group that focused on learning Python and an advanced group working with the actual dataset. In the first group, we taught members the basics of computer programming—such as control flow, functions, and objects—and introduced them to the concept and implementation of neural networks in Keras. We also completed multiple mini-projects to practice coding skills. In the advanced group, we focused on analyzing the dataset we will be using—BOLD 5000—and constructing a data pipeline to transform the data into an algorithm-usable format. We have successfully implemented pipelines for getting both image data and fMRI data from the dataset; the codes can be found on our GitHub page:

Quarter Membership Roster

Lyna Dinh

Audrey Dunn

Johnson Zhou

Shenghua Zhu

Sample image from the dataset (a) without and (b) with outlines of individual objects.

Simulation for Tracking Elementary Particles

In-House

Managed by Xiaohe Shen **Contact: xiaohe.shen@yahoo.com**

Project Description

Simulation is a crucial component of physics research. It provides important information for the behavior of the object of the researcher's interest. The design of the experiments and the interpretation of the experimental data heavily relies on the accuracy of the simulation results. It is important to not only know how to choose the most ideal simulation model, but also to ensure that the models are producing valid results. In this project, we are going to explore the world of elementary particles from a theoretical perspective by learning some basic programming skills, running simulations using different models, and comparing our results with experimental or analytical ones.

Quarter Project Highlights

This quarter we focused on building the team members' skills in programming with Python to prepare them for doing the actual simulations next quarter.

We went through programming syntax and explored the basic computational operators. Members were taught the concept of variables, functions, parameters, lists, and arrays. They were also familiarized with using packages, such as Numpy.

Topics were reinforced through programming assignments whose solutions were compared in order to study the best methods and implementations. At the end of the quarter, we learned some simple but important algorithms for the purpose of physical simulations. These algorithms were later applied modeling physical phenomena in order to reinforce previously learned topics. We simulated the motion of a particle with different accelerations and plotted the corresponding trajectories.

Quarter Membership Roster

Kexin Yan

Ziyi Zeng

Yujie Wan

Rishbabh Singh

Kelving Nguyen

Winter 2020 Projects Update

All projects listed above are currently taking members as space allows. We will also be adding two new projects within the first few weeks of the quarter. Apply through our website:
upsilonlab.pa.ucla.edu/join-member

Winter 2020 Goals

We would like Winter 2020 to continue on with the same enthusiasm and dedication seen from our members and managers in the previous quarters. We hope to attract more active members and help them develop skills that will prepare them for internships, official research positions, and their studies. To best accomplish this, we require the help of ambitious students in the department to join the Upsilon Lab manager team so that we can continue spreading the skills and knowledge necessary to succeed in future career and research endeavours.

Adding more managers to our organization is critical for Upsilon Lab's ability to include all interested students. It is also an excellent way to hone programming skills, practice teaching, and inspire others into more advanced research positions. If you are interested in becoming an Upsilon Lab manager, please apply through our website:

upsilonlab.pa.ucla.edu/join-manager

Winter 2020 New Projects

We are excited to announce the addition of a new project:

Efficient Electricity, In-House

Managed by Siggi Galam

Apply for these new and continuing projects through our website at: upsilonlab.org/join-member

Special Thanks

The Presidents would like to thank:

- The Physics & Astronomy Department for their support of Upsilon Lab.
- The Advisory Board for their invaluable advice throughout the course of the quarter.
- Chris Regan for becoming Upsilon Lab's advisor
- All of the professors who have sponsored projects in the previous quarters. Thank you for your willingness to help the department undergraduates learn about physics from a research perspective.