



WPI

Crafting Astronomy Lab

An Interactive Qualifying Project Report

Submitted to the Faculty of the

WORCESTER POLYTECHNIC INSTITUTE

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Abstract:

This IQP focuses on crafting eleven lab manuals for an Introductory Astronomy course. These manuals cover a wide range of Astronomical concepts from fundamental to advanced topics. Modern experimental methodologies and approaches used by astronomers worldwide are implemented as these labs being developed. This course is designed as a great start-off course for students at junior standings to get familiarized in experimental astrophysics without requirement in prior advanced knowledge of Astronomy.

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Background:

WPI's Physics department has recently launched the Astrophysics Minor program. Adding more courses in the field of astronomy/astrophysics to our current curriculum is in great demand to support such a program. The purpose of my IQP is to develop lab manuals for a new junior-level Astronomy Lab course. As a freshman at WPI (in 2014) I wanted to explore the beautiful field of Astronomy and Astrophysics. But no such curriculum or course existed at that point. With some of my colleagues who share the common interest, I approached Professor Germano S. Iannacchione (department chair back then), Professor Frank Dick (founder of the astrophysics minor program), and Professor Shanshan L. Rodriguez (astrophysicist) about starting a new curriculum and adding new courses related to Astrophysics/ Astronomy. In 2015-16, Astrophysics Minor program was approved with students' interests and demand, which was a tremendous success for all us. In order to enrich this new program, I discussed with Professor Shanshan L. Rodriguez and Professor Frank Dick about performing my IQP on 'Crafting Astronomy Labs' for a new Astronomy course. Throughout A, B and C terms of 2016-17 academic year, we have developed 11 individual lab manuals during this IQP, which are planned to be used in the experimental astronomy lab course in D'19.

Introduction:

A set of 11 individual labs for an Astronomy Lab course will be introduced in this lab manual. The Astronomy course will be geared towards students with Junior Academic Standing. It is assumed that students have taken introductory Physics courses (PH110/11, PH1120/21, PH1130, PH1140) and have a good knowledge of geometry. But no previous knowledge in Astronomy/ Astrophysics is required. This lab manual will be equally helpful for physics students thinking about pursuing a career in Astronomy and students from other majors who are interested in exploring the beautiful field of Astronomy. The manuals cover a wide range of topics spanning astronomical unit conversion, introduction to astronomical scales to complex physical phenomenon like Doppler Shift, Black Body radiation, hands-on experiments for parallax measurement and advanced image analysis techniques commonly used by modern Astronomers worldwide. These manuals will engage students in a unique manner by first introducing theoretical concepts and then providing tools that astronomers use daily to deal with some of the most interesting questions asked in Astronomy. A large part of the exercises depends on computer-based software and web-based tools so computers with network access and certain required software installed are mandatory. Based on student feedbacks, I've also developed a course structure/ schedule that will work best with this lab manual. In order to ensure the quality of contents of these manuals, I consulted with structures and manuals of similar Astronomy Lab courses offered in other US universities.

Project Summary:

Course Structure:

The first goal of this IQP was to figure out the best possible course structure/schedule that fit our current physics curriculum, preferably during C/D term. I reviewed three main aspects: course contents (given 7-week constraint and student prior background), course schedule and available facilities. Here is one possible course structure:

- a. Instructor will decide on 7 (or 6) labs from the bunch of 11 labs based on background and interest of registered students.
- b. There will be two sessions per week. The first session will be a 1-hour long session in a classroom lecture style, taking place at the beginning of the week (Monday and Tuesday), where the instructor introduces concepts and software that will be used in the actual lab sessions. The second session will be a 3-hour long actual lab session, taking place in a lab room with computer and internet access, where students will work in a group of two but submit individual lab report.
- c. Additional equipment, such as theodolites, telescopes, spectrometers with light sources will be setup for the students in the lab sessions.

Summary of Individual Labs:

1. Scales of the Universe:

This is the first lab in the sequence. This lab is about units, unit conversions, different scales of measurements, significant figures, ratios, basic geometries and trigonometry. In a way this lab teaches and tests the basic mathematical and scientific notational knowledge required to be best

prepared to perform all the other labs. Each section starts with a brief introduction and explanation, some worked out example and then asks question related to the topics. This lab doesn't have a prelab also doesn't require the use of a computer.

2. Spectral Classification of Stars:

The spectral classification system will be introduced in Lab 2. Students will use the spectrum of known spectral type stars to visually determine the spectral type of unknown stars. Students will use the Luminosity to Mass relationship for main sequence stars to construct a Hertzsprung-Russell diagram. (M67 and another older cluster). Then they will use GEAS web applications to learn more about HR diagram. Finally, students will also learn about how to calculate radius of some of the stars based on Mass and Luminosity.

3. Using the Charts:

In this lab, students will first build their own Star Wheel and then answer questions based on the use of this Star Wheel. They will also learn about Equatorial Coordinate System.

4. Blackbody Radiation:

In this lab, students will first learn about the spectral curves. Next, they will learn and answer questions on Black Body radiation. At last they will explore more about blackbody radiation using an online applet from University of Nebraska –Lincoln. (Permission is granted for non-commercial usage as long as it remains unmodified)

5. Doppler Shift:

In this lab, students will learn about Doppler shift and its usage while determining velocity and motion of far galaxies and other astronomical objects. Students will also learn about red-shift, blue-shift and perform some exercises on these concepts. At last they will explore more about Doppler shift using another online applet from University of Nebraska –Lincoln. (Permission is granted for non-commercial usage as long as it remains unmodified)

6. Parallax Angle, Calculating Distance to an object:

In this lab, students will learn about parallax angle technique to measure distances to objects. Students will perform experiments with Theodolite and taking angle measurements. Later, they will calculate distances based on parallax angle method and sine law of equivalence. A full instruction on how to set up and use theodolite is given in the lab manual.

7. Parallax Angle, Calculating Radius of the Church Ball:

In this lab, students will again use theodolite to perform angle measurements and then use parallax angle method to calculate the radius of the ball at the top of Trinity Church. (Or another object determined by the instructor). Similar method is used to calculate radius of galaxies.

8. Parallax Angle, Calculating distance between two objects:

In this lab, students will use theodolite to calculate distance between two objects. Similar methods are used to calculate distance between two astronomical objects.

9. Finding Stellar Distances using parallax:

After learning how to use theodolites to perform parallax measurements, students will learn how to apply this knowledge to calculate stellar distances.

10. Basic Image Analysis:

Students will learn to use basic image analysis tools used by Astronomers. Students will use ds9 software (free to download software from Harvard Smithsonian. One of the most powerful software available). Students will learn to work with FITS files and calculate radius, mass etc. of two astronomical objects m42 and m57. (FITS files will be provided)

11. Tri Color Imaging Analysis:

Students will again use ds9. But this time they will learn to create Tri-colored RGB images from multiple FITS image files. They will learn how to access the vast databases of FITS files from different archives of telescopes like Hubble, Chandra, STSI, Sloan galaxy survey etc. Superimposing catalog objects will also be introduced.

Conclusion:

This lab course will be a unique addition to WPI's Physics curriculum. Being a standalone course, this course will be appealing to both Physics Majors and Non Majors. The lab manuals are structured in a way such that students not familiar with some of the most fundamental concepts in Physics will gain in-depth knowledge of these theories while applying the knowledge in solving problems related to Astronomy. It has been an absolute pleasure for me to explore various tools, softwares, materials necessary to develop these labs and I'm confident these labs would be a great addition to WPI's Astrophysics program.