Physics 650 – Research Methods in Physics & Astronomy – Spring Semester 2013

Instructors

This course is being taught this semester by three faculty members of the Department of Physics & Astronomy –

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Objectives

This course is a survey of research methodologies that in this term are drawn primarily from astronomy and astrophysics, but are broadly applicable for graduate students who are engaged in doctoral level research. With the objective of providing useful tools and a perspective on how advanced scientific research is conducted, we will cover three topics:

1. On-line resources, databases, and use of LaTeX for scientific writing (Williger)
2. Programming for data analysis, modeling, and instrument control (Kielkopf)
3. Optical spectroscopy and statistical methods (Lauroesch)

This is a required course for students in the doctoral program in Physics & Astronomy.

Requirements

Students should be enrolled in the graduate program in Physics & Astronomy or have comparable experience.

You are expected to

1. Attend and participate in all classes
2. Study the in-class, text, and on-line material for the topics
3. Respond in a timely way to homework assignments
4. Develop a culminating project that uses the topics of the class
5. Present the project at the conclusion of the course

Blackboard and other websites

The gateway for this course is the University's Blackboard system,

`http://blackboard.louisville.edu/`

which offers access to announcements and to grades. Your University *User ID* and *Password* are required to log into Blackboard.

There will be other websites used in this class to support the topics covered, and they will be linked on Blackboard and described in class meetings. This departmental site

`http://prancer.physics.louisville.edu/classes/650`.

may also provide links to useful resources:

Textbooks, software, and computer access

Topic 2 on programming has a required textbook:

Learning Python, Fourth Edition, O'Reilly, 2009, by Mark Lutz(ISBN 978-0-596-15806-4). It is available new and used from Amazon in paperback, and in a Kindle versions, and from the publisher in various open E-book formats.

You will need access to a computer connected to the Internet on which you can load and run software. Most laptop computers running OSX, Windows, or Linux will fill this need. Current tablet computers may not, because of operating system limitations. For those who prefer desktop access, the department's computing resources are available, including consoles in the astronomy lab, the computational physics cluster, and graduate student labs and offices. We do not require proprietary software, but we may ask that you install Open Source or free software.

Topic 1 – On-line resources – Williger

We begin the course with guidance on the use of on-line research resources, specifically those useful for astronomy and astrophysics. We will look at various public databases for physics and astronomy research literature, astronomical catalogs, and astronomical data. Additionally we will cover the use of LaTeX for scientific writing, and the preparation of research reports and manuscripts for publication.

Topic 2 – Programming – Kielkopf

In this topic we will introduce you to writing your own programs using Python with examples drawn from astronomy and astrophysics. We will discuss the merits (and pitfalls) of programming in contrast to using commercial or community-based programs, and compare commonly used languages and tools. Python was chosen for the course because it is free, flexible, and now widely used in physics, astronomy, space science, and engineering. We will use the time available to help you develop core skills that you can turn to in your own research. Prior experience with programming is not required, but the skills developed here may be useful if you want to explore other languages or programming systems.

Topic 3 – Spectroscopy & Statistics – Lauroesch

The concluding topic is optical astronomical spectroscopy and statistical methods. While examples of spectrocopy will be drawn specifically from astronomy, the same concepts and methodology apply to other disciplines in the physical sciences. The material will help you understand how optical spectroscopic instruments work, how the digital data are transformed into flux-calibrated spectra, and how those spectra are used to explore the physics of the source of the light. In addition statistical methods for understanding measurements, especially survival analysis for the treatment of upper and lower limits, will be explored.

Project and presentation

In the final class sessions each student will present a project that they have been working on through the semester. The choice of project should be made to make use of one or more of the topics covered in the class, and the presentation should focus on that aspect of the work. The subject may be a new individual inquiry, a part of doctoral research program, or a part of a larger effort with collaborators in this class or elsewhere. In the case of collaborative work, however, the presentation should focus on the contributions of the student.

Grades

The course letter grade will be the average of the 3 grades for each topic assigned by the faculty teaching that topic, and a grade on the project assigned jointly by all faculty teaching the course.

Caveats

We reserve the right to make changes in the syllabus when necessary to meet learning objectives, or when there is a technical or software issue that requires a change in content or methodology. Any changes will be announced in class, by email, and posted in the current on-line syllabus and schedule.

Syllabus version of January 5, 2013.

Schedule and Content

8 January and 10 January Databases

15 January and 17 January Databases

22 January and 24 January Databases

29 January and 31 January Databases

5 February Databases

7 February Why program? Choosing a language. Simple Python.
Chapters 1. to 4.

12 February Data types: numbers and strings
Chapters 4, 5, 7.

14 February Lists, tuples, and statements
Chapters 8, 9, 10.

19 February Assignments and flow control
Chapters 11, 12, 13.

21 February Functions
Chapters 16, 17, 18.

26 February Scientific computing with Numpy and Scipy

28 February Matplotlib and graphics

5 March Handling astronomical FITS files with Pyfits

7 March Image processing with PIL and f2n

11 March to 17 March *Spring break*

19 March and 21 March Calibration and Extraction of Spectra from 2D Images

26 March and 28 March Analysis of Emission and Absorption Features

2 April and 4 April Multi-Object and Non-Optical Spectroscopy

9 April and 11 April Statistical Methods Including Survival Analysis

16 April Other Statistical Techniques

18 April Project presentations

Class schedule version of January 5, 2013 May be subject to change to meet the learning objectives.