

Observational Techniques in Astronomy

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Description:

This is a graduate level introductory astronomy course focused on the concepts of photon detection, calibration and scientific inference using data from modern telescopes. In addition to the theoretical lessons, students will be working through the full process of reducing scientific data to produce publishable results. The course will include hands-on classwork covering the basics of optical photometry and spectroscopy, as well as a short introduction to proposal writing.

Pre-requisites: Basics of programming in Python, a laptop with a Linux-based operating system or virtual machine. All other tools and techniques will be introduced in the course. Familiarity with the astronomy concepts introduced and covered in this course is desirable but not mandatory.

Module 1: (Anirban Dutta, 4 lectures, 8h)

This module covers the basic principles of astronomical photon detection and the extraction of scientific data from those signals. It also covers how signals are lost and distorted due to the atmosphere and instruments, and how we correct for them. Concepts related to signal-to-noise, PSF, different methods of detecting signals/photons in different wavelengths will be discussed. Finally, we will end with a deep dive into CCDs.

The 4 lectures will closely follow *Astronomical Measurements* by Andy Lawrence. (Chapter 1, 2, 3 and 4 respectively)

Exam: There will be one take-home exam for this module.

HW: Each week, there will be a short HW (questions from the book mostly).

Module 2: (Fraser Gillan, 7 hours)

This module takes students from the initial idea for an observing project through to the acquisition and reduction of data. Through a combination of theoretical instruction and guided practical exercises, students will work through the preparation and interpretation of observing charts and develop target prioritisation strategies under realistic constraints. Students will then learn about the practical aspects of in-person telescope observing, with a brief overview of remote and queue-scheduled modes. Students will examine how atmospheric effects, such as airmass and seeing, influence data quality and will work through the transformation of raw telescope images into scientifically usable data using standard reduction procedures (bias, dark, and flat-field corrections). The module also introduces the process of selecting an appropriate facility, applying for telescope time, and drafting a competitive observing proposal, with students preparing a structured mock proposal based on their developed observing plan.

Exam: Students will be asked to prepare a mock telescope proposal using what they have learned.

Non-exam but expected outcome: They will be required to use the images they have reduced in this module for subsequent exercises in other modules.

Module 3: (Nandini Hazra, 8 hours)

This module will introduce the concepts of optical photometry. Students will start from reduced images (obtained by the student in the previous module and/or directly from the telescope archives) and learn to process them to measure fluxes, magnitudes, photometric and morphometric properties. Concepts of zero point calibration, object detection and deblending which are central to exercises of photometry will also be covered. Aperture and PSF photometry will be included in the exercises. Students will also learn how to identify and synthesize PSFs from astronomical images and datasets. As a part of the technical skills, students will also learn how to set up virtual isolated code environments to implement and test relevant code.

References: Relevant chapters from “*Galactic Astronomy*” (Binney & Merrifield) and “*Fundamental Astronomy*” (Karttunen, Kröger, Oja, Poutanen and Donner) will be used. All relevant reference material will be provided in/before class.

Exam: Evaluation will be through continuous assessment and class participation as well as completion of exercises as assigned in class.

Module 4: (Priscila Pessi, 7hours)

This module provides an introduction to astronomical spectroscopy, starting with the fundamental concepts of what a spectrum is and how it reveals key physical properties of astronomical objects. Students will explore the processes by which light is dispersed and recorded, and how spectral features can be interpreted to infer composition, motion, and other characteristics. Building on the calibration techniques introduced in Module 2, students will gain hands-on experience obtaining and reducing spectra from archival data, including steps such as background subtraction, wavelength calibration, and noise mitigation. By the end of the module, students will be able to produce fully reduced, scientifically meaningful spectra ready for analysis and interpretation.

Exam: Assessment for this module will be based on a practical assignment in which students must demonstrate the successful production of a reduced spectrum.

Expected Outcomes

The students will have an overall understanding of how astronomical signals are detected, reduced, and the challenges arising from noise and imperfections of the instruments. (especially in optical wavelengths). They will have an understanding of how instrumental signatures are removed from the signals and then calibrated using standard stars and a coordinate system. Students will also be able to interpret photometric and spectroscopic results to draw astrophysical conclusions.

Collaboration between students is strongly encouraged (but academic dishonesty is not). Every participating student enrolled in the course is expected to put in their own effort to solve the HWs/assignments/exams, as well as be able to answer questions regarding the logic and methodology followed by them to arrive at their solutions.

Office Hours: By appointment, either in person or online

Evaluation: Each module will have its own evaluation (equally weighted) and the final grade will be decided by instructors together.