PHYS/ASTR 5015: Observational Methods and Data Analysis

This course will provide an introduction to instrumentation in optical astronomy, analysis of data and image processing, and observational techniques. The student will develop the ability to plan observations and produce a final scientific result using real data. The course will emphasize the capabilities and limitations of optical observation and provide insight into current research.

Course Website:
www.physics.utah.edu/~kdawson/courses/p5015

Meeting Times:
M: 3:05-3:55 JFB 210
MW: 7:15-10:00 South Physics 205

Instructor and contact info:
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Office Hours:
By appointment

Prerequisites: Familiarity with computer programming. ASTR 3060 or enrollment in the Department of Physics and Astronomy graduate program.

Textbooks: There are two textbooks that will be used in this class. Both will serve as excellent references in the future.
"Data Reduction and Error Analysis for the Physical Sciences", Bevington and Robinson, 2002. Required text.
"Handbook of CCD Astronomy", Howell, 2006. Recommended but not required.

Essential topics: The student will learn the fundamentals behind optical astronomy:
- Detector performance
- Signal and noise
- Acquisition and processing of data
- Techniques in data analysis
- Interpretation of data leading to a scientific result

Course description: This class will introduce the student to the fundamentals of optical astronomy. At the end of the semester, the student will have the background in observations and data analysis to begin research in observational optical astronomy.

The class will begin with a two week observing session with the local telescopes on the South Physics rooftop. We will acquire data and do a quick analysis using windows-based software tools. The purpose of these first two weeks is to simply introduce the student to the basics of observational astronomy and foster familiarity with the stages of data reduction.

Next, we will leave the Windows environment and proceed with an overview of the IDL programming language on the Linux cluster. This language is easy to learn for a person who has used Mathematica, Matlab, or has experience computer programming. Specific routines in the IDL language are already available for astronomical data analysis and will be used throughout the semester.

The introduction to IDL will be followed by a discussion of the fundamentals of charge-coupled devices, the detectors that are used to collect optical astronomical data. The student will learn how data is collected at the telescope and examine the calibration images that are used to determine CCD performance such as read noise, dark current, and gain. Images taken from the camera at the Frisco Peak Observatory will be used in this analysis.

During the discussion of CCDs and calibration, the student will examine data from a ground-based optical telescope. This data will provide the foundation for the remaining course material and for the student research projects. The semester will progress with development of the processing routines that will improve the raw data into a final image. These routines will be used in photometry, astrometry, and calibration to interpret the data for scientific measurements. Among other possibilities, these measurements will include Cepheid and SN lightcurves, stellar dimming due to transits of known extrasolar planets, Hertzsprung-Russell diagrams, and properties of galaxies in massive clusters. In the process, the student will develop a good understanding of statistics, measurement uncertainties, and the capabilities of ground-based optical telescopes.

Student projects: Early in the semester, students will choose two projects with guidance from the instructor. The first project will focus on a specific part of the data reduction pipeline. The student will write a technical report discussing general data reductions and the results of their work toward implementing the data pipeline.

The second project will use new optical data to reproduce a famous discovery that changed the way we understand our universe. Other ideas for the second project could be used to complement current research being performed by the student or to complement research within the astronomy program at the University of Utah. Each student will write a second technical report describing their program and present the results to the class.

The material covered in classroom lectures will parallel the analysis of the student research project. For example, the lessons from the lecture on bias subtraction, dark current removal, and flat-fielding will be applied directly to the raw data that is used in the first student project. By the end of the semester, the new data will be analyzed and interpreted within the scientific context that motivated the observations.

Semester schedule:

Week 1: Introduction to observing and data analysis with South Physics observatory
- perform calibration exposures and imaging of open cluster
- Data acquisition and telescope control
- Telescope operation and planning observations

Week 2: Charge-coupled device (CCD) operation and performance
- Description of charge collection, electronics, and readout

Week 3: Introduction to observing with Frisco Peak Observatory
- Discussion of science behind student projects, selection of project
- Examples of science, observations, and data for student projects

Week 4: Introduction to IDL programming
- Basic code, basic programming language

Week 5-6: Weekend Field trip to Frisco Peak Observatory
- Characterization of CCDs
- Measurements of bias levels, read noise, and other characteristics of CCDs

Week 7-8: CCD imaging
- Effects of atmosphere and other terrestrial inconveniences on data quality
- Photometry and astrometry
- Discussion of calibration and alignment of images

Week 9: Measurement techniques for aperture photometry
- Measuring signal in the presence of noise and background light

Week 10: Student projects due, discussion of projects

Week 11-13: Statistics and noise
- Characterization of measurement errors
- Correlated noise
- Effects of resampling on image statistics

Week 14: Presentation of student projects

Week 15: Final work on student projects and reports

Evaluation: Students' evaluations will be based equally on the two student projects. There will be no final exam or midterm. Students will work in teams of two on each project, but will be required to turn in a report that represents their own independent work. The first project will be due on November 4, 2013 and will cover a part of the data reduction pipeline. The second project will be due on December 20, the last day of finals week. Each paper should be written in Latex, compiled into a PDF file, and contain 10-15 pages of single spaced text, including figures.

Students are encouraged to work with the other students in the class and consult the professor in charge of the class when in need of help. Office hours are by appointment, students are encouraged to review drafts of their projects with the professor before the due date.