AST 325/326
(Introduction to) Practical Astronomy
Syllabus Fall 2019

Lecture, Lab Instruction & Toturial, Office Hours:

- ***Lecture**: Monday, 4:00–5:00 pm, RS 208*
- ***Lab Instruction & Tutorial**:*
  Monday, 5:30 –6:30 pm, AB 105 (Computer Room)
  Tuesday, 5:30 –6:30 pm, AB 105 (Computer Room)
  (Note: The hours for Lab Instruction & Tutorial may be changed later. You only need to attend one of the sessions.)
- ***Late-night Telescope Sessions:***
  A few late-night telescope sessions will be scheduled using the campus telescope.
- ***Regular Office Hours**:*
  Instructor Office Hours: 11:00am–12:00 pm, Monday (see below for the room number)
  TA Office Hours: 11:00am–12:00 pm, Thursday and Friday, AB 105 (Computer Room)
  (Note: Individual appointments outside the regular office hours can be arranged. You can request an appointment using email.)
  Additional online sessions by programing supporter.

Course Webpage & Email:

http://www.astro.utoronto.ca/~astrolab/
astrolab@astro.utoronto.ca (use this one for class email to all instructors and TAs as well as for submitting your assignments)
Please check the webpage during the course for new material and class updates. Note that this is outside the Quercus system because of the combined class activities for AST325 and AST326.

Instructors:

Professor Dae-Sik Moon, moon@astro.utoronto.ca (AB128)
Professor Suresh Sivanandam, sivanandam@dunlap.utoronto.ca (AB120)

Teaching Assistants and Program Suipporter:

Siqi Liu, sqliu@astro.utoronto.ca (AB210) (TA)
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Thomas Cassanelli, cassanelli@astro.utoronto.ca (AB52) (TA)
Alex Lague, lague@astro.utoronto.ca (MP1416) (Program Supporter for more general questions about programming)

Equipment and Telescope Manager:

Michael Williams, williams@astro.utoronto.ca (AB214)

1 Overview

In this course AST325/326 we will learn how to analyze and address research challenges that integrate core astronomy curriculum material with state-of- the-art technical coursework. This astronomy lab provides instruction in modern astronomical techniques, while providing an advanced learning environment where students can become adept in the use of research methods and tools that form the foundation of modern practical methods in the physical sciences. Thus, this class serves not just those seeking advanced professional skills because they are on a trajectory to graduate school in astronomy and astrophysics, but also those who want to apply their astronomy knowledge in a broader context (e.g., in remote sensing or medical imaging).

2 Learning Objectives

This course assumes that each student has strong background knowledge of freshman physics (classical mechanics, E&M, simple circuits, elementary quantum mechanics), math (linear algebra, multivariate calculus), and a rudimentary knowledge of astronomical phenomenology.

Our astronomical learning objectives are:

1. Develop familiarity with basic astronomical observational methods and instruments
    a. Detection of light and fundamental limitations to measurement
        i. Photoelectric effect
        ii. Detector noise, dark current, and gain
        iii. Electric fields, wave propagation and interference
        iv. Thermal noise
    b. Stellar Photometry and Astrometry
        i. Quantitative analysis of astronomical images
    c. Spectroscopy
        i. Operation of dispersive spectrometers
        ii. Operation of coherent spectrometers
        iii. Heterodyne receivers
        iv. Line and continuum sources
        v. Wavelength calibration
        vi. Spectra of astronomical sources
    d. Telescopes and astronomical imaging
        i. Imaging properties of a telescope
        ii. Coordinate transformations and astronomical coordinate systems

<u>Underlying these are the following technical topics:</u>

2. Quantitative understanding of the statistical properties of data
    a. Random processes and probability
    b. Probability functions
        i. Binomial, Poisson, and Gaussian ("normal") distributions
    c. Descriptive statistics
        i. Histograms and cumulative distributions
        ii. Moments and expectation values
        iii. Confidence intervals
    d. Error
        i. Standard error for repeated measurements
        ii. Weighted mean
    e. Maximum likelihood and least squares for parameter estimation
        i. Linear problems
    f. Signals and noise
        i. Band-limited signals, resampling, and interpolation
        ii. Linear systems, transfer functions, Fourier transforms, and convolution
        iii. Detection of signal in the presence of noise
3. Understanding and correcting systematic errors
    a. Accuracy vs. precision
    b. Identification, measurement, and correction of systematic effects
4. Display of quantitative information
    a. Tools for exploration of data
    b. Effective presentation of one- and two-dimensional data
    c. Methods for comparing data and model predictions
5. Scientific writing and communications

   a. Professional writing skills
      i. Planning and outlining a report
      ii. Style and content
      iii. Proofreading and revision
   b. Combining text and graphics to make quantitative arguments
   c. Effective oral presentations
6. Acquisition and manipulation of large data sets
   a. Computer aided data acquisition
      i. Counting
      ii. A/D conversion
   b. Data storage and data structure

3 Sequence of Labs, Schedule, & Logistics

In Fall 2019, we will conduct three activities. These labs are conceived as sequential, where each subsequent lab builds on the previous one. The labs focus on: 1) statistics of photon detection; 2) spectroscopy; and 3) astrometry.

- In Lab 1 **"Basic Photon Statistics"** we will learn how photons are detected using the photoelectric effect with a charge coupled device (CCD). Then we will learn basic statistics needed to analyze photon data, and will apply statistical analysis methods to sample data, starting from one-dimensional data and expanding to two-dimensional data. Rigorous error analyses will be introduced.
- In Lab 2 **"Introduction to Spectroscopy"** we will conduct a simple experiment using an optical grating spectrometer and a CCD array. The CCD array is used as the sensor in a spectrometer that is used to observe sources of continuum (tungsten lamp) and line (Ne and Hg discharge lamps) radiation. We will establish characteristics of the spectrometer including the wavelength calibration and the noise properties of the CCD using error propagation and elementary linear least- squares methods. We will make our first astronomical observations by recording the spectra of several different spectral type stars. We may also analyze sample observational to calculate a Doppler shift of an astronomical source.
- In Lab 3 **"Astrometry from CCD Images"** we will use CCD images to measure the positions of stars relative to the celestial coordinate system and determine proper motions of asteroids. The purpose of this activity is to learn astronomical skills that we will apply to track the position of some minor planets (asteroids) over several weeks. For this lab we will begin by using data that is already posted on the webpage so that we can get off to a quick start and determine the properties of the imaging camera and CCD. You will learn how to query astronomical databases, and plan and execute your own observational program for determining the proper motion of asteroids.

3.1 Tentative Course and Lab Schedule for Fall AST325/326

Lab 1: <u>Basic Photon Statistics</u>

- Monday, September 9 – Logistics and Intro Lecture for Lab 1
- Monday, September 16 – Mini-Lecture and Lab 1; Group Choices Due
- Monday, September 23 – Group Led Discussion and Mini-Lecture
- Monday, September 30 – Group Led Discussion and Mini-Lecture
    - **Wednesday, Oct 2 – Lab 1 due electronically by 11:59 pm**

Lab 2: <u>Introduction to Spectroscopy</u>

- Monday, October 7 – Overview of Lab 2
- *(Monday, October 14 – No class, Thanksgiving)*

- Monday, October 21 – Group Led Discussion and Mini-Lecture
- Monday, October 28 – Group Led Discussion and Mini-Lecture
- *(Monday, Nov 4 – No class, Reading Week)*
    - **Wednesday, November 6 – Lab 2 due electronically by 11:59 pm**

Lab 3: Introduction to Astrometry

- Monday, November 11 – Overview of Lab 3
- Monday, November 18 – Group Led Discussion and Mini-Lecture
- Monday, November 25 – Group Led Discussion and Mini-Lecture
- Monday, December 2 – Group Led Discussion and Mini-Lecture
    - **Wednesday, December 4 – Lab 3 due electronically by 11:59 pm**

3.2 Access to the Computer Room (AB 105)

The undergraduate lab, AB105, is available throughout the semester for you to work on your lab assignment at your convenience. The front doors of AB should be unlocked through 9PM. Access to AB 105 is a privilege, so **do not share your card key with anyone not enrolled in the class**. We trust you to act responsibly; please do not do anything that might prevent us from being able to offer this freedom to subsequent classes. AB 105 is primarily for lab work, but you should also consider it a place to study, hang out, or enjoy other quiet activities that do not make it difficult for others to work. You must avoid doing anything that compromise this purpose, including smoking and use of drugs or alcohol. Please check with the undergraduate coordinator Andrew Apong (AB101A; ungrad.sec@astro.utoronto.ca) to activate your card key.

3.2 Drop in consulting & office hours

You can use Lab Instruction & Tutorial as well as TA Office hours, both at AB 105 (Computer Room), for dropping in consultation. This is a good opportunity to ask questions and get help, including those related to execution of the lab.

4 Organization

4.1 Instruction

At the start of each new lab the instructor will use lectures and related handouts to provide an overview of the lab and review background material relevant to the current investigation. We will give hands-on demonstrations and provide on-line tutorial to introduce computer skills (Linux), programming (Python) and document preparation (LaTex).

4.2 Lab groups

We designed the AST 325/326 lab investigations to be executed by lab teams, not individuals. The first reason is that real science is a team endeavor—the notion of the solitary genius revolutionizing science is a myth. The second is that these lab activities are ambitious. A concerted effort by you and your teammates is necessary for success. It is crucial that you learn how to work in a team and be respectful of each other’s learning throughout this course. There are too many challenges for you to accomplish lab assignments single-handedly. Each member of your team should take primary responsibility for various aspects of the experiment: writing a Python program designed for a specific calculation; acquiring some data; working out a piece of math, etc. This does not mean that you can ignore that aspect of the lab. It is your responsibility to understand and execute your task and to understand what your partners are doing. You must establish mutual trust by explaining to your partners what you are doing and having them explain what they are doing. If you do not understand what your group is up to you cannot tell if they are screwing up! If you do not know what your lab partners are doing you will not be able to write your lab report. **Your measurements and analysis will be a team effort, but your final written report must be yours alone.**

Lab groups typically consist of 3 or 4 students, although 2 or 5 may be possible under special circumstance allowed by the instructor. It is preferable to have all teams of the same size, but this may not be possible. ***Lab groups need to be finalized by the class on September 16. If you cannot form your own group by then, the instructor will sign your group for yourself.*** Lab groups are not immutable; however, you must seek the instructor's permission to change the composition of a group. At the discretion of the instructor lab groups may be reconstituted.

4.3 Group led discussions

On intermediate dates between the start and completion of a given lab, class may begin with a presentation and discussion, termed "Group led discussions." Each week, a different lab group will facilitate this discussion and presentation. When your group is tasked with leading the discussion, you are required to meet with your team prior to class to decide on a list of discussion topics. These topics may include common sticking points, potential sources of error, and avenues for exploration outside of those in the lab handout. During class, each group member should take the lead on presenting a different discussion topic. **You will be graded on the quality of your chosen discussion topics, the unique insights you bring to the discussion, your presentation style, and the degree to which you stimulate class participation.**

5 Evaluation

Written lab reports are the principal means of evaluation. As in the professional world, an accurate, complete, and clear presentation of results and conclusions together with a convincing presentation of the evidence and reasoning forms the basis of evaluation. The class web page describes how to write a good lab report. The lab report grading scheme is detailed in § 5.5. Your contribution to "Group Led Discussions" will be evaluated as outlined in § 4.3.

5.1 Deadlines

You must submit your lab report before the deadlines listed in § 3.1. You are welcome to submit your final lab report to the instructor any time before the final due time. ***Lab reports submitted after the deadline will not be graded.*** If you have a compelling reason for needing extra time, you may submit a request for a deadline extension. You must submit your request (including explanation) 48 hours prior to the deadline. *No retroactive extensions will be granted except in the case of documented medical emergencies*.

5.2 Final exam

There is no final exam.

5.3 Credit assignment

The distribution of your final grade is as follows:

- Lab report #1: 30%
- Lab report #2: 30%
- Lab report #3: 30%
- Group-Led Discussions: 10%

Note: For AST326 students your final grade of the year will be determined between your performance Fall semester and Winter semester 50/50. There will be a new syllabus given out at the beginning of the Winter semester that outlines the new credit assignment for that semester.

5.4 Plagiarism and behaviour on academic matters

This is a lab course and your work will be graded based on the originality of your own work and documentation in your individual lab reports.

The University of Toronto rules regarding behavior on academic matters are here:
http://www.governingcouncil.utoronto.ca/policies/behaveac.htm

University rules regarding plagiarism are summarized at:
http://www.chem.utoronto.ca/undergrad/plagiarism.php

5.5 Lab report rubric

***All lab reports must be written by you alone* – you may share measurements and analysis efforts from your team but the overall content and presentation between lab members should be unique.** Each lab is worth a total of 75 points (pts):

- Overall Lab Quality & Participation [25 pts]:
  - Overall structure & Style 10 pts
  - Attendance & Participation 10 pts
  - Format 5 pts
- Lab report sections [50 pts]:
  - Abstract 5 pts
  - Introduction 10 pts
  - Observations & Data 5 pts
  - Data reduction & Methods 5 pts
  - Data analysis & Modeling 10 pts
  - Discussion 10 pts
  - Appendix (presentation of code and/or detailed analysis) 5 pts

The following tables explain the grading schemes for lab reports. Please review each table so you are familiar with what is expected of you.

Attendance & Participation [10 pts]	
10	Lab classes were well attended and there was *active* participation between you and the group team members and the lab activity and measurements.
8	Lab classes were well attended and there was *some* participation between you and the group team members and the lab activity and measurements.
6	Lab classes were well attended and there was *minimal* participation between you and the group team members and the lab activity and measurements.
4	Lab classes were *not well* attended (missed more than 2) and/or there was *little* participation between you and the group team members and the lab activity and measurements.
2	Many lab classes were *missed* and/or there was *little-to-no* participation between you and the group team members and the lab activity and measurements.

Overall Structure & Style [10 pts]	
10	The lab report reads as a narrative describing the group's and individual's activities. The overall goal and methods are clear from the beginning and serve as a key driver throughout the text. The report follows a logical structure on all scales, from sentences, to paragraphs, to sections, to subsections, and conveys the maximum amount of information in the minimum number of words. The activities described demonstrate initiative and creativity on the part of the individual.
8	The overall structure of the report, including the experimental goals and methods, are clear throughout, though perhaps uninspiring. The text is mostly clear, but the balance between sections may be slightly off, or some phrases may be awkward. The report is complete but contains no new or surprising insights.
6	The report as a whole contains significant organizational flaws. The experiment purpose may be buried, or key results may be inadequately described. The text may not flow well, or may be confusing at times.
4	The lab report is poorly structured. The experimental purpose may be unclear. Key figures or tables may be present but without explanation.
2	Organization and logical structure are absent. The experimental purpose is unclear, and the lab is incomplete.

Format [5 pts] – Each column is the total # points for each topic	
1	Contains title, date, name, contact information, lab group, and any division of labor.
1	Does not exceed 10 pages (including tables and figures).
1	Minimum 10-point font is used.
1	Proper spelling is used throughout the report
1	Proper grammar is used throughout the report. Complete sentences are required, unless a list or table is identified. Grammar and spelling will be considered in the overall structure & style of the report rubric as well.

Abstract [5 pts]	
5	Succinctly states the objectives, methods, and principle conclusions of the experiment.
4	Less succinct, may contain some off-topic statements but states the key objectives, methods, and conclusions.
3	Verbose, lacks focus, may be missing key components of the lab summary.
2	Verbose, follows the lab handout extremely closely, conveys only a tenuous understanding of the lab's purpose.
1	Verbose, does not reflect the actual purpose of the lab, contains details or irrelevant information.

Introduction [10 pts]	
10	Concisely motivates the problem and introduces the methods used in pursuing it.
8	Less concise, may contain irrelevant information that detracts from the central purpose but states the overall goal and the key methods.
6	Verbose, lacks focus, the purpose of the lab is not central, and the key methods may not be introduced.
4	Verbose, draws excessively from the lab handout, methods are not introduced.
2	Verbose, the purpose of the lab is not clear, methods are not introduced.

Observations & Data [5 pts]	
5	Describes the equipment used and how the data were acquired. Provides a clear log or summary of the observations, containing the observation times, dates, personnel involved, etc. Summarizes any anomalies or systematic errors that may be present in the data.
4	All important information for the data acquisition is present, but there may be organizational or logical lapses. Potential anomalies and systematic errors are described.
3	Mediocre organization, some relevant observational information may be missing or not adequately described. Possible systematic errors are not described.
2	Poor organization, key observational information needed to reproduce the experiment may be missing, anomalies are not described.
1	Poor organization, the given information is inadequate for the reader to successfully repeat the experiment, anomalies are not described.

Data Reduction & Methods [5 pts]	
5	Describes data reduction methods/algorithms, as well as statistical methods used to analyze the data or combine it into the final result. Methods used to estimate uncertainties in the data are clearly explained. The reader is adequately led through intermediate to final results with each consecutive step clearly explained.
4	Data reduction and uncertainty estimation techniques are present, but each step may not be fully explained. The reader may not be fully convinced that the results and uncertainties are correct.
3	Some data reduction techniques are listed, but the description lacks organization and clarity. Uncertainty estimates may be missing or incorrect.
2	Data reductions steps are only partially described, and some steps may be incorrect. Uncertainty estimates are absent or in error.
1	Key steps in the data reduction process are not described in the text. Error estimates are absent. The reduction steps are likely in error.

Data Analysis & Modeling [10 pts]	
10	Demonstrates complete understanding of the physical principles underlying the experiment. Intermediate calculations with plots or tables appear in a logical sequence throughout and are sufficient to convince the reader that the final results are correct. All equations used appear in the text with equation numbers and references. Equations are described and explained as part of sentences within the context of the experiment, and all new symbolic quantities are defined. Figures and tables have clear captions, numbers, and labels, are referred to in the body of the report, are placed in the text close to where they are referenced, and are used to support key arguments in the text.
8	Demonstrates nearly complete understanding of physical principles. Intermediate calculations are present, and the organization is fairly clear. All equations used are listed and mostly explained. Figures and tables are used throughout to support key arguments in the text. Calculations appear generally correct and complete, but may contain some minor errors.
6	Shows partial understanding of the relevant physical principles. Intermediate calculations may be sparse, and organization may be lacking. Equations are listed but may not be adequately explained. Figures and tables may appear without reference in the text. Important calculations may be absent or contain major computational errors.
4	Shows limited understanding of the relevant physical principles. Intermediate calculations may be absent, and organization is unclear. Key equations may be missing, poorly explained, or in error. Key figures and tables may be absent, or demonstrate major computational errors.
2	Shows very little understanding of the relevant physical principles. No attempt at the end result may be present, let alone intermediate calculations. Organization is unclear, equations are missing or in error, and important figures or tables are absent without explanation.

Discussion [10 pts]	
10	Synthesizes, analyzes, and interprets the results in the context of the experimental purpose. Compares results achieved with theoretical expectations. Explains discrepancies between theory and results appropriately in terms of errors in measurement and technique. Describes remaining ambiguities, uncertainties, and avenues for future investigation. Includes an insightful summary of conclusions.
8	Reiterates the main results with some ties to the experimental purpose. Compares results achieved with theoretical expectations. Explains discrepancies between theory and results but may contain omissions or oversights. The summary may needlessly repeat information described previously in the report without revealing new insights.
6	Reiterates the main results with some ties to the experimental purpose. Compares results achieved with theoretical expectations but explanations for discrepancies may be vague or wordy. The summary may needlessly repeat information described previously in the report without revealing new insights.

4	Main results may not be clear, or may not be tied to the original purpose of the experiment. Comparison with theory may be excluded or may contain significant errors. Concluding remarks may be absent.
2	Main results are not given, and the text is not tied to the introduction. Comparison with theory and concluding remarks may be sparse or completely absent.

Appendix [5 pts]	
5	The appendix should include a presentation of code that was written in-house (i.e. by members of your group) to perform pertinent reductions and analysis in the lab activity. Essential pieces of the code should be presented in the appendix with brief text that *well describes and presents the key portion of the code used in the lab*. The main body of the text should refer to these sections in the appendix.
4	The appendix includes the essential in-house code used in the lab activity, but the text in the appendix weakly describes and presents the code relating to the lab results.
3	The appendix includes minimal portions of the essential in-house code used in the lab activity, and the text weakly describes and presents the code relating to the lab results.
2	The appendix includes minimal portions of in-house code used in the lab activity, and poorly describes and presents the code relating to the lab results.
1	The appendix does not include in-house code used in the lab activity, and minimally describes any of the code and lab results.