ASTP 711-01: Advanced Statistical Methods for Astrophysics

Syllabus and Course Information – Fall Semester 2022

2022 August 23

Course Information

Lectures:
TÞ 11:00-12:15 GOS(08)-3310 beginning 2022 August 23 and ending 2022 December 1

Holidays (no lecture):
Oct. 11 (Fall Break); Nov. 24 (Thanksgiving).

Instructor:
Dr. John T. Whelan; LAC(74)-2063, 475-5083;
`john.whelan@astro.rit.edu`
Office Hours: via Zoom `https://rit.zoom.us/j/93305450336` MR 3pm-4:30pm or by appointment.
(Please email to make an appointment.)

Course Website:
`http://ccrg.rit.edu/~whelan/ASTP-711/`
Most material posted at `http://mycourses.rit.edu/`

0.1 Computing Environment

We will make extensive use in this course of Jupyter notebooks (running Python 3.9) for lessons, homework and exams. There is a JupyterHub environment in which you can run these, or if you prefer, you can install the Anaconda Individual edition from `https://www.anaconda.com/products/individual` (or any other Python/Jupyter installation that works for you).

Required Textbook:

- Gregory, P., *Bayesian Logical Data Analysis for the Physical Sciences* (Cambridge, 2005)

Recommended Additional Texts:

- Sivia, D. S. with Skilling, J., *Data Analysis: A Bayesian Tutorial*, 2nd edition (Oxford, 2006)
- Hilbe, J. M., de Souza, R. S., and Ishida, E. E. O.,*Bayesian Models for Astrophysical Data* (Cambridge, 2017)
- Gelman, A., Hill, J., and Vehtari, A., *Regression and Other Stories*, 3rd edition (Cambridge, 2020)

Other possibly useful references:

- Wall, J. V. and Jenkins, C. R., *Practical Statistics for Astronomers* (Cambridge, 2003)
- Gelman, A., Carlin, J. B., Stern, H. S., Dunson, D. B., Vehtari, A., and Rubin, D. B., *Bayesian Data Analysis*, 3rd edition (CRC, 2013)
- McElreath, R., *Statistical Rethinking: A Bayesian Course with Examples in R and Stan*, 2nd edition (CRC, 2020)
- Wasserman, L., *All of Statistics: A Concise Course in Statistical Inference* (Springer, 2004)
- Cowan, G., *Statistical Data Analysis* (Oxford, 1998)
- Jaynes, E. T., *Probability Theory: The Logic of Science* (Cambridge, 2003)
- Casella, G. and Berger, R. L., *Statistical Inference*, 2nd edition (Brooks-Cole/Cengage, 2002)
- Bendat, J. S. and Piersol, A. G., *Random Data: Analysis and Measurement Procedures* (Wiley, 2000)
- Press, W. H., Teukolsky, S. A., Vetterling, W. T., and Flannery, B. P., *Numerical recipes: the art of scientific computing* (Cambridge, 2007)
- Arfken, G. B., Weber, H. J., and Harris, F., *Mathematical Methods for Physicists, Seventh Edition: A Comprehensive Guide*, 7th edition (Academic Press, 2012)

Prerequisites:
Graduate standing in a science or engineering program or permission of instructor.

Potential Topics:

1 Probability Theory
  - 1.1 Fundamentals of probability theory (Bayesian and frequentist interpretations)
  - 1.2 Probability distribution functions (discrete and continuous)
  - 1.3 Specific probability distributions
  - 1.4 Gaussian approximation to probability distributions
  - 1.5 Sums of random variables and the central limit theorem

2 Statistical Inference
  - 2.1 Bayesian and frequentist approaches
  - 2.2 Hypothesis testing and model selection
  - 2.3 Parameter estimation and errors

3 Models and Computational Methods
  - 3.1 Linear models and regression
  - 3.2 Generalized linear models and logistic regression
  - 3.3 Markov Chain Monte Carlo

Exams:
Two preliminary exams, format TBA, currently planned for the week of September 26 and the week of October 31.
Final exam (cumulative) scheduled for Tuesday, December 13 10:45am-1:15pm, GOS(08)-3310.

Discussion Board:
There is a discussion board in mycourses, on which you are encouraged to ask about and discuss both conceptual and practical aspects of the week's materials with me and your peers.

Slack Workspace:
If you prefer to use Slack to discuss the course with me and your peers, we will have a workspace at `https://RIT-STAT-711-whelan.slack.com/`

Homework:
Quasi-weekly problem sets, and possibly one or more longer-term projects. The problem sets are in the form of a Jupyter notebook, and are to be completed by including notebook cells with LaTeX/markdown (for explanations and formal calculations) and Python commands (for numerical computations). Problem sets should be turned in with all of the cells executed. Solutions in the form of executed notebooks will be made available after the problem set is due. Problem sets will not be accepted after the solutions have been released.

Course Policies

COVID Considerations:
Public health protections have unfortunately been replaced by individual actions, but we should all do our best to keep each other safe. Since this is a relatively small class, I'm not planning to stream lectures over Zoom by default, but if any of you need to quarantine or isolate, or if public health conditions are unsafe, please contact me, and we will try to make appropriate arrangements.

Please wear a good fitting mask covering your nose, mouth and chin for any indoor, in-person activities. Students are also encouraged to protect themselves with a full set of vaccinations including applicable boosters, and by wearing a high-quality mask such as N95/FFP3 or KN95/KF94/FFP2.

Attendance:
There is no attendance grade for the course, and no penalty for missing class. However, most students will find themselves at a disadvantage on the homeworks and exams if they neglect to take advantage of the full range of tools (including both lectures and reading) to gain understanding of the material.

Collaboration:
Collective brainstorming is a time-honored tool of scientists attacking a problem, be they freshmen or tenured professors. That said, working through the homework problems is an important aid to gaining mastery of the material, and a student who simply transcribes the solution of another student or of the group will likely have trouble come exam time. In light of this, solutions which are clearly (in my judgement) transcriptions from other sources or from each other will receive reduced or no credit. You should use outside sources or group discussions as needed to get the idea of how to do a problem, then go off and write up your own solution.

Additionally, in the interest of learning proper academic procedures, you should acknowledge any outside help you get on homeworks, whether from other students or from references outside the textbook.

Working together on exams or copying off of someone else's test is of course cheating and will not be tolerated.

Grades:
Grades will be based on the following components:

25%	Problem Sets
20%	First Prelim Exam
20%	Second Prelim Exam
35%	Final Exam

Your score on each component of the course (each prelim, the final, all the homeworks together, and class participation) will be converted to a numerical "grade point" score, and the weighted average of those five scores will be your final grade, converted to a letter grade according to the scale above.

Grading Scale:

A	3.83–4.5
A-	3.5–3.83
B+	3.17–3.5
B	2.83–3.17
B-	2.5–2.83
C+	2.17–2.5
C	1.83–2.17
C-	1.5–1.83
D	0.5–1.5
F	(-0.5)–0.5

Special Arrangements for Students with Disabilities:
Students with disabilities who wish to receive accommodations in this class should contact the Academic Accommodations Office at 475-2023 or via their website
`http://www.rit.edu/studentaffairs/disabilityservices/accommodations.php`
as soon as possible so that warranted accommodations can be implemented in a timely fashion. The Academic Accommodations Office is located in SAU(04)-1150.