ASTR 503/703: Structure and Evolution of Galaxies
a.k.a., Galastrostats
Physics & Astronomy Department, Fall 2016

Course Catalog Description: Internal dynamics and structure of galaxies; physics of star formation, active galactic nuclei, and galaxy interactions; large-scale clustering and environment-dependent physical processes; evolution of the galaxy population over cosmic time.

Unofficial Description: This course has been redesigned as a computing intensive course in which students learn astrostatistics methods while deeply engaging with specific topics in modern galaxy research. The first half of the course will provide background via computational methods tutorials and interactive exploration of galaxy data sets, while the second half will be largely devoted to in-depth team projects. Thus the goal of this course is *not* a broad overview of galaxies, but retainable and translatable knowledge acquired through highly hands-on, in-depth learning about specific topics and practical research methods.

Sequencing: Elective course for astrophysics majors (503) or graduate students (703). Prerequisites of ASTR 301, MATH 383, and PHYS 331 or permission of the instructor.

Instructor of Record: Sheila Kannappan (professork@unc.edu; 919-962-3486; Phillips 290)
Teaching Assistant: Rohan Isaac (rohan@unc.edu; Chapman 134)

Course Website: *https://github.com/galastrostats/general/wiki*

Schedule
Class in Chapman 235 MWF 10:10-11am
Scheduled Lab Time in Chapman 134 __MWF 8-10 __MWF 11-1 __MW 2:30-5:30
Individual Meetings by appointment (email Professor or TA)

Texts
- Galaxies in the Universe. L. S. Sparke and J. S. Gallagher, III.
- Statistics, Data Mining, and Machine Learning in Astronomy: A Practical Python Guide for the Analysis of Survey Data. Z. Ivezic, A. J. Connolly, J. T. VanderPlas, & A. Gray.

These texts are both available from the library and the Ivezic text is offered as a free pdf download for UNC students. Thus neither text is strictly required for purchase, although the Ivezic text is highly recommended.

Warning**:** Unlike most courses in physics and astronomy, this course is not and cannot be laid out for you in a simple, cumulative order. The Ivezic text is a resource compilation rather than a traditional textbook, and Sparke & Gallagher will be used as a reference book rather than for its pedagogical presentation. Jump around in these books, or on the internet, to form your own synthesis! That's how research works.

Exams
1) *Midterm:* There will be a 3-hour take-home midterm challenge requiring you to address an open-ended problem working alone with access to texts, notes, and codes. This exam will be distributed Sept. 30th and you will have one hour to finish it during class Oct. 3rd. (Dates subject to change.)
2) *Final:* Friday Dec. 16th 8-11am in Chapman 235.

Homework
In this class, of the 9 hours of homework typical for a three credit-hour class, at least 6 hours should be spent on computing. Thus you will be assigned to one of the three computer lab times above to work on tutorials and projects with access to the professor, TA, and other classmates (for work with partners/teams).

Projects
Each student will complete a mini project in weeks 2-3 to get comfortable downloading and analyzing data to answer a question. In week 6 students will work in small teams to plan final projects, given some project ideas and guidelines. These projects will be completed in weeks 7-14 and presented in weeks 15-16.

Presentations
- *VoxCharta* – Starting in week 7, each student will vote for the most interesting new astrophysics abstracts at http://unc.voxcharta.org/ on an assigned day of the week. The professor will lead discussion of a few of the most popular and relevant abstracts in class. Each student will also choose one article to read and review in a half-hour class presentation during weeks 7-14, ideally related to his/her team project. Either slides or handouts are fine.
- *Computational Methods* – During weeks 7-14, each student will volunteer once to give a half-hour class presentation on a computational methods topic related to his/her team project, with attention to how it works in practice (e.g., providing a demo, discussing setup details, etc.). Slides, handouts, and hands-on demos with code distribution are all fine.
- *Final Team Project* – In weeks 15-16, each team will give a half-hour presentation on the methods and conclusions of their project, with every team member contributing at least 5 minutes of the presentation. These presentations should be polished at the level of a talk for a conference. All slides, no handouts or hands-on elements.

Grades

Attendance/Participation (including tutorials, mini project, VoxCharta)	35%
Midterm Challenge	5%
Individual Presentations (10%)	
- computational methods presentation	5%
- VoxCharta article presentation	5%
Team Project (45%)	
- project proposal	5%
- jupyter notebook progress reviews (3 x 5)	15%
- final jupyter notebook	20%
- final presentation	5%
Final Exam	5%

Note: Attendance is always expected. Attendance includes assigned computer lab time.

How to Succeed in this Course
1. Attend all classes and lab times.
2. Don't just read tutorials, ***do*** everything in them. Tactile/visual typing memory is powerful.
3. Read all assigned parts of the Ivezic text, with attention to the read vs. skim info on the calendar.
4. Unless told otherwise, always bring your laptop to class. It is optional during lab time.
5. Complete work on time. Extensions will be granted only for severe health or family emergency.
6. Ask for help if you need it!

Calendar *(subject to revision – see https://github.com/galastrostats/general/wiki/Syllabus)*

Levels of Reading Assignment:
- **Bold** = Read fully for understanding
- Plain Text = Skim for awareness
- *Italics* = Note for future reference (read titles only or enough text to understand titles)

Week 1: WF Aug 24/26 Intro + Sign-Up for Computer Lab Times

Reading Week 1: Ivezic 1.1, 1.2, *1.3*, 1.4, 1.4.1-1.4.2, *1.5*, *1.5.** [note use of * = "all" as in linux]
Class Week 1:

- Class Overview
- Galaxies as a Population I
- Demos

Computer Lab Week 1: (** = best if you work with a partner)

- Linux Tutorial** - Parts I+III required, II optional
- Vi Tutorial
- Git and GitHub Tutorial**
- Python Tutorial 1 (data analysis basics)

Week 2: MWF Aug 29/31/Sep 2 + Assigned Lab Times

Reading Week 2: Ivezic **1.6, 1.6.1-1.6.2,** *1.6.3*, **1.7, Appendix A**, Ch. 2, *2.1.1*, 2.1.2, **2.2**, *2.3-2.4*
[Actually download the code to make Figs. 1.9-1.12 on your machine, and look at the code!]
Class Week 2:

- Galaxies as a Population II
- Guided exploration of galaxy properties with RESOLVE, ECO, sql, and python
- Basic Stats

Computer Lab Week 2:

- Python Tutorial 2 (programming basics)
- Debug and speed up sample code
- Choose and start mini projects

Week 3: WF Sep 7/9 + Assigned Lab Times

Reading Week 3: Ivezic Ch. **3, 3.1.1,** 3.1.2, **3.1.3-3.1.4, 3.2**, 3.2.1, **3.2.2, 3.3, 3.3.1-3.3.2,** 3.3.3, **3.3.4,**3.3.5, *3.3.6-3.3.11,* **3.4,** *3.5.**, **3.6, 3.6.1, 3.7**
Class Week 3:

- Galaxies as a Population III
- More guided exploration of galaxy properties (add SDSS)
- More Basic Stats

Computer Lab Week 3:

- Tutorials (Monte Carlo Methods, Correlation Testing)
- Finish mini projects

Week 4: MWF Sep 12/14/16 + Assigned Lab Times

Reading Week 4: Ivezic Ch. **4, 4.1, 4.2, 4.2.1-4.2.3,** 4.2.4-4.2.5, **4.2.6,**, 4.2.7-4.2.8, **4.3, 4.3.*,** *4.4*, **4.5**
Class Week 4:

- More Basic Stats
- Present mini projects

Computer Lab Week 4:

- Tutorials (Interpreting Chi Squared, Bootstrapping)

Week 5: MWF Sep 19/21/23 + Assigned Lab Times

Reading Week 5: Ivezic **4.6,** *4.6.1,* **4.7,** 4.7.1-4.7.2, *4.7.3-4.7.6,* 4.8, **4.8.1-4.8.2,** *4.9, 4.9.**, **5.1, 5.1.*, 5.2, 5.2.1,** *5.2.2-5.2.4,* **5.3, 5.3.*, 5.4,** 5.4.*, **8.11, 8.11.1-8.11.4**

Class Week 5:

- Bayesian Statistics
- Histograms and Distributions (applications to luminosity and mass functions)
- Selection Effects, Stacking, Survival Analysis (applications to luminosity and mass functions)

Computer Lab Week 5:

- Tutorials (Fitting a Line, Hypothesis Testing and Cross-Validation)

Week 6: MWF Sep 26/28/30 + Assigned Lab Times

Reading Week 6: Ivezic 5.5, **5.6, 5.6.1,** *5.6.2-5.6.7,* 5.7.*, **5.8, 5.8.1-5.8.3,** 5.8.4-5.8.5, *5.8.6,* **5.9**, *browse all sections of Chapters 6-9*

Class Week 6:

- Step through sample projects (MCMC vs. "brute force" Bayesian fitting, PCA analysis of spectra)
- Review project criteria
- Discuss potential team projects
- Receive take-home midterm challenge

Computer Lab Week 6:

- Examine possible projects with team
- Write up team project plan using form provided and get it approved

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Weeks 7-14 Overview

Reading for Weeks 7-14:

- as needed for team project
- VoxCharta abstracts and voting, each student one day per week

Class pattern for Weeks 7-14:

- two days for student half-hour presentations (astrophysics articles and computational methods)
- one day split between computational tools and tricks (TT) and VoxCharta discussion

Computer Lab for Weeks 7-14: 6 hours per week spent on project at assigned group computer lab times

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Week 7: M Oct 3 finish midterm in class WF Oct 5/7 student presenters + Assigned Lab Times
Weeks 8-14: MW student presenters; F VoxCharta/TT + Assigned Lab Times (no class F Oct. 21)

TT Topics:

1. use of jupyter notebooks (tunneling, exporting to LaTeX, jupyter/ipython notebook conversion)
2. advanced linux tools (screen, fg/bg, top, ps and top, aliases, wc, which, grep, locate, etc.)
3. data analysis with pandas
4. visualization with seaborn
5. automating OS and code interactions with pexpect
6. python multi-threading

Weeks 15-16: M Nov 28 and MW Dec 5/7 Final Team Presentations