ASTRON 3550: Stellar Structure and Evolution
Course Syllabus

Revised February 4, 2015

Basic Course Information

Term: 2154 (Spring 2015)
Credits: 3
Meeting Time: Monday & Wednesday, 3:00 to 4:15 PM, Thaw Hall room 210
(Note: The second floor of Thaw corresponds to the 5th floor of SRCC or the 3rd floor of OEH.)

Instructor

Prof. Carles Badenes
Office: 309 Allen Hall
Office Hours: Monday & Wednesday 11:00 AM to 12:00 PM (or by appointment)
Email: badenes@pitt.edu (email is generally the best way to contact me)
Phone: (412) 624-9039

Office Hours

I will hold regular office hours from 11:00 AM to 12:00 PM on Mondays and Wednesdays. If you cannot make these times, please contact me and we can arrange to meet at another time.

Course Description and Objectives

This is an advanced graduate course intended for students who want to pursue a research-oriented career in astrophysics. The goal of the course is to understand the structure and evolution of stars, and their observational properties, using known laws of physics, and to apply this understanding to a state-of-the-art code for stellar evolution, `MESA`.

Stellar astrophysics is a fascinating subject that brings together basic concepts from quantum mechanics, relativity, nuclear physics, and thermodynamics in a setting where densities, pressures and temperatures take on extremely high values. The lecture material will include *very* brief reviews of the required concepts, but previous knowledge of these topics is a requisite to take ASTRON 3550. Making clear connections between fundamental physics and the properties of stars is the first key objective of the course.

`MESA` stands for Modules for Experiments in Stellar Astrophysics. Learning how to install, run, and modify `MESA` to suit your needs is the second key objective of the course. `MESA` is an open-source, modular, parallelizable code that solves the equations of stellar structure in 1D. As a community resource, `MESA` has revolutionized the way stellar astrophysics is done, forcing a transition to a more open and collaborative model that shares many elements with the open-source movement in software engineering. The `MESA` user community is large and very active, and the code and its capabilities are continuously expanded by individual researchers, taking advantage of the modular structure. By using `MESA`, you agree to become a member of the user community and to adhere to the `MESA` manifesto (yes, there is a manifesto, and you should read it carefully). You can find more information about `MESA` here: `http://mesa.sourceforge.net`.

Textbook

Stellar astrophysics is a mature subject, and several excellent textbooks are available that cover most of the course topics, as well as many aspects that we will not see in detail. In the lectures, I will follow the notes by Onno Pols, available at `http://astro.ru.nl/~onnop/education/stev_utrecht_notes/`, with occasional detours to illustrate key concepts using `MESA`. These lecture notes are quite good, but they contain occasional mistakes and typos, and some chapters are very brief. In particular, the notes do not cover stellar atmospheres, stellar evolution in binary systems, or stellar populations, which we will address in the last part of the course. If you want to pursue the study of stellar astrophysics on your own, I recommend you buy a published textbook. The most popular is the classic *Stellar Structure and Evolution*, by Kippenhahn & Weigert (Springer, 1996), on which the Pols notes are based, but it is a bit formal and outdated. Other good books in the 'classic' tradition are *Principles of Stellar Evolution and Nucleosynthesis* by Clayton (Chicago, 1968) and *Stellar Interiors* by Hansen, Kawaler, and Trimble (Springer, 2004). More updated textbooks have been published by Iben (*Stellar Evolution*, Cambridge, 2013, two volumes) and Prialnik (*Theory of Stellar Structure and Evolution*, Cambridge 2009). Finally, a somewhat lower level (advanced undergraduate), but very well presented and clear introduction to the topic can be found in *The Physics of Stars* by Phillips (2nd edition, Wiley, 1998).

Course Grades

There will be no exams for this course. The final grade will be determined as follows;

Homework (20 %) Homework assignments will be posted on Courseweb (see below), and will require the use of `MESA`.

Final project (80 %) The final project will be a non-trivial piece of research in some aspect of stellar evolution to be conducted with `MESA`, ideally by groups of two students. I will provide some suggestions for final project topics, but students are encouraged to propose their own ideas. The final project will have three main parts, which will be graded separately:

- A written **project proposal** that will clearly define the goals of the project, explain why it is relevant in a broad scientific context, outline a strategy to implement the project within `MESA`, and estimate the amount of effort that will be required. Project proposals will be due on **Monday, February 16**. The proposal will be worth **20 %** of the final grade.

- An oral **project presentation** to be given during Finals Week. This will be a 20 minute talk, with 5 minutes for questions, outlining the main goal of the project, its scientific significance, and its main results. The presentation will be graded on its quality, independently from the final report and the degree of success in the implementation of the project itself. The presentation will be worth **20 %** of the final grade.

- A written **project report** due at the end of the course on **Monday, April 27**, describing the methodology employed, the main results of the project, their scientific significance, and avenues for future research. The report will be worth **40 %** of the final grade.

Course Outline Detail

Here is a rough outline of what will be covered in the course. This plan may be modified according to student interests and questions that may arise during the course, the pace at which we proceed, and the progress that you make in the use of `MESA`.

Week 1 (Jan 5, 7)	Introduction. Mechanical and thermal equilibrium (Pols Ch. 1, 2)
Week 2 (Jan 12, 14)	Equation of State (Pols Ch. 3.1, 3.2, 3.3)
Week 3 (Jan 21)	Adiabatic Processes (Pols Ch. 3.4)
Week 4 (Jan 26, 28)	Energy transport: radiation, conduction, opacity (Pols Ch. 5.1, 5.2, 5.3, 5.4)
Week 5 (Feb 2, 4)	Energy transport: convection (Pols Ch. 5.5)
Week 6 (Feb 9, 11)	Nuclear reactions (Pols Ch. 6)
Week 7 (Feb 16, 18)	Stellar Models and stability criteria (Pols Ch. 7)
Week 8 (Feb 23, 25)	Stellar Evolution: Basic principles (Pols Ch. 8)
Week 9 (Mar 2, 4)	Stellar Evolution: Star Formation and Main Sequence (Pols Ch. 9)
Mar 8-15: Spring Break	
Week 10 (Mar 16, 18)	Stellar Evolution: He burning and late evolution of intermediate-mass stars (Pols Ch. 10, 11)
Week 11 (Mar 23, 25)	Pre-supernova evolution of massive stars and core collapse supernovae (Pols Ch. 12, 13)
Week 12 (Mar 30, Apr 1)	Basics of interacting binaries. Thermonuclear (Type Ia) supernovae
Week 13 (Apr 6, 8)	Basics of Stellar Atmospheres
Week 14 (Apr 13, 15)	Basics of Stellar Populations
Apr 18-25: Finals Week	Presentation of the **final projects**

CourseWeb

The University of Pittsburgh provides a web based resource called Courseweb, which is a portal to web sites for individual courses. A Courseweb site for this course has been created and there you can view announcements and download course materials. To access Courseweb go to http://courseweb.pitt.edu. Use your Pitt email username and password to login to Courseweb. If you have forgotten your username and password or need to set up an account, contact the help desk at 412-624-4357, or 4-HELP. Once you have logged into the system simply click on the link for this course to access the available material.

Academic Integrity

Students in this course will be expected to comply with the University of Pittsburgh's Policy on Academic Integrity. Any student suspected of violating this obligation for any reason during the semester will be required to participate in the procedural process, initiated at the instructor level, as outlined in the University Guidelines on Academic Integrity. This may include, but is not limited to, the confiscation of the examination of any individual suspected of violating University Policy. Furthermore, no student may bring any unauthorized materials to an exam, including dictionaries and programmable calculators.

Disability Services

If you have a disability for which you are or may be requesting an accommodation, you are encouraged to contact both your instructor and Disability Resources and Services (DRS), 140 William Pitt Union, (412) 648-7890, drsrecep@pitt.edu, (412) 228-5347 for P3 ASL users, as early as possible in the term. DRS will verify your disability and determine reasonable accommodations for this course.

Accessibility

CourseWeb/Blackboard is ADA Compliant and has fully implemented the final accessibility standards for electronic and information technology covered by Section 508 of the Rehabilitation Act Amendments of 1998. Please note that, due to the flexibility provided in this product, it is possible for some material to inadvertently fall outside of these guidelines.

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Statement on Classroom Recording

To ensure the free and open discussion of ideas, students may not record classroom lectures, discussion and/or activities without the advance written permission of the instructor, and any such recording properly approved in advance can be used solely for the student's own private use.