ASTRONOMY 440 - Astrophysics of Stars

Fall Semester 2014 (Sched. #20322)

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Office Hours: T 10 A M-12 NOO N, W 3-5 PM; or by appointment
Prerequisites: Credit or registration in MATH 342A (Methods of Applied Mathematics) and PHYS 354 (Modern Physics)

Lectures: MWF at 2:00-2:50 PM in Physical Sciences (PS) 256

Textbook: An Introduction to Modern Astrophysics (Carroll and Ostlie)

Midterm Exam: Friday, October 17, 2014.

Final Exam: Monday, December 15, 2014 at 1:00 PM in PS 256.

Course Description:
Radiative transfer theory, atmospheres of stars and the emergent spectrum, interior structure and evolution of stars, stellar pulsations.

Student Learning Outcomes:
During this semester, my goals for you as students are:

• to characterize stars utilizing spectroscopy and photometry of starlight. Starlight helps us to comprehend all of astronomy: from planets to galaxies to the universe. Because stars produce much of the light we can detect, they communicate information about themselves and their neighborhoods, and the light can be used to probe the universe between them and us. We need to understand how radiation and matter interact, and how we can exploit this to learn about the characteristics and chemical composition of stars from afar.

• to demonstrate an understanding of the physics that is used to model the structure of stars. Stars employ physical principles covering a huge range - from interactions between elementary particles (like electrons, protons, neutrons, and photons) to supernova explosions that affect entire stars and their surroundings. Stars have taught us new physics and can teach us more.

• to distinguish the different types of stars, how they change ("evolve") over time, and how they die from astronomical observations. Physical principles have consequences for stars, and if we fully understand them, we can make predictions about their lives that we can check against observations. The interaction between theory and observations is critical for astronomy and science in general.

• to assess an astronomical situation using simple physics calculations. This is a very important skill in deciding where to put your research time to get the most return, but in a practical sense, it is also important for the physics GRE test (which some of you may end up
taking). By understanding time and other order-of-magnitude scale arguments (related to length, mass, and energy), and being able to use simplified models, you should be able to apply your knowledge to determine what is most important in problems you study.

- to improve your ability to interpret scientific results and communicate them in a clear manner. To be an effective scientist, you need to be able to comprehend the research of others, and to be able to clearly and effectively express the importance of your own work.

**Grading Policy**

The course grade will be based on

- **Midterm Exam** (25% of grade)
- **Final Exam** (25%)
- **Homework Assignments** (40%)
- **Written Report** (10%)

The homework assignments will generally be composed of problems that ask you to do calculations to give you more familiarity with important topics covered in class; back-of-the-envelope type problems that will ask you to simply model unfamiliar situations; short essays asking you to clearly explain the physics involved in some aspect of stars; and some exercises asking you to collect and examine astronomical data from archives. **IMPORTANT NOTE:** it is OK to work together on homework assignments, but you MUST write your solutions in a way that makes it clear you have thought about things yourself.

The midterm and final exams will mostly be composed of short answer and essay questions that will test your physical understanding of the material, and there will be a small number of problems like the more involved ones from the homework assignments. Both exams will be closed-book. The midterm exam will be given in class, while the final exam will be given during finals week.

The written report is intended to get you to start thinking about astronomy as more than a class --- it is a science, and our understanding of the universe is continuously changing. In the last month of the class you will be asked to select a topic of current interest, research it, and write a report (up to 10 pages) discussing background, the physical principles involved, the role stars play, and how it all relates to answering "big questions" in astronomy. I expect to see evidence that you have made strong attempts to understand the topic and write a description in your own words. I also require that you have a complete listing of the references you used. **PLAGIARISM IS NOT TOLERATED.** A list of potential topics is given at the end of the syllabus.

More details about the format of the paper will be given toward the end of the semester when the report assignment is passed out, but it will be due in the last week of class.

**FOR STUDENTS WITH DISABILITIES:** If you are a student with a disability and believe you will need accommodations for this class, it is your responsibility to contact Student Disability Services at (619) 594-6473. To avoid any delay in the receipt of your accommodations, you should contact Student Disability Services as soon as possible. Please note that accommodations are not retroactive, and that accommodations based upon disability cannot be provided until you have presented your instructor with an accommodation letter from Student Disability Services. Your cooperation is appreciated.

**Reference List**

The class textbook is the best one I know of for this class: it has a lot of up-to-date material on astronomy research, and many examples of how to do simple but illuminating calculations. However, the books listed below can be used to supplement the book and class notes. They can be all be found at the University Library. The ones listed with "*" are most appropriate for the
Some Potential Topics for the Final Paper

- The first generation of stars (Population III) --- how did they form? why don't we see them now?
- Determining characteristics of extrasolar planets that transit (partially eclipse) their stars --- why is a knowledge of star properties necessary for accurate measurements?
- The age of the Sun and solar system from radioactive elements in meteoroids
- Determining age using color-magnitude diagrams of populations of stars
- Determining age using radioactive elements in old stars
- Supernovae in cosmology --- how did they become accurate probes of the universe?
- Gamma ray bursts --- what are the likely causes?
- Planetary nebulae --- How do they form? What is responsible for their shape and appearance?
- Pulsating stars (like Cepheids or RR Lyraes) and their use for determining distances
- Helioseismology (or asteroseismology) --- what can it tell us about stellar interiors?
- Chemical enrichment/pollution of galaxies by dying stars --- what are the main kinds of polluters, what chemical elements do they contribute, and why?
- Dense stars (white dwarfs or neutron stars) and matter at high density
- Properties of brown dwarfs --- what distinguishes them from stars?
- The most massive stars (M > 50 M\textsubscript{Sun}) --- how do they age? what physics critically affects their evolution?
- History of star formation in galaxies from color-magnitude diagrams

Course Outline

Please keep in mind that the schedule of topics is subject to change. The reading that you will be responsible for is indicated beside each major topic, and the rough amount of time devoted to each topic is also included.

- Using Light from Stars (Chapters 3, 5, 8; 1 week)
  - spectroscopy
  - photometry
  - spectral types
  - the color-magnitude diagram (CMD)
  - the role of star mass
- Stellar Atmospheres and Microscopic Physics (Chapter 9; 3 weeks)
  - the radiative transport equation
  - simple atmosphere models
- the formation of spectral lines
  - application: measuring chemical composition
- Stellar Structure (Chapter 10, Section 16-3, Section 11-1; 7 weeks)
  - mass continuity
  - hydrostatic equilibrium
    - the equation of state
    - the pressure integral
    - degeneracy
  - conservation of energy
    - the Virial Theorem
    - nuclear reactions
      - basic reaction rate calculations
      - major energy-producing reactions
  - energy transport
    - radiation
      - opacity
    - convection
    - conduction
    - neutrinos
  - composition equations
    - application: timescales
  - simple models of stars
  - the structure of the Sun
- Stellar Evolution (Chapters 13, 15, 16; 4 weeks)
  - star formation and pre-main sequence stars
  - main sequence
    - application: measuring age
  - the evolution of 1, 5, and 20 solar mass stars
  - star corpses