ASTRONOMY 450: STELLAR ASTROPHYSICS

Fall 2016 [class # **50849R**] **Syllabus** Dr. Däppen

Classes meet:	MW 2-3:50pm, GFS 104
Office/Contact:	SHS 370, 740-1316, e-mail: `dappen@usc.edu`
Office hours:	Monday 11am-12noon (SHS 370) &
	W 3:50-5pm (from classroom to SHS 370),
	and by appointment (arranged in person, by phone, or e-mail)
Departmental Office:	ACB 439 , 740-0848
Departmental-TA Office:	ACB 431 (hours TBA)

Course description (Catalogue):

Observation and theory of stellar atmospheres and stellar interiors. Theory of stellar evolution. Physical and astronomical significance of the end states of stellar evolution.

Prerequisite:

PHYS 153L or PHYS 163L.

Expanded course description:

The scope of this course is an introduction to *stellar* astrophysics, which is the observation of stars and the theory of stellar structure and evolution. As a theoretical astrophysicist, I will undoubtedly stress the PHYSICS in astrophysics by showing how many branches of physics come together in our understanding of stars. This is the case not only in the study of stellar atmospheres, but above all in the understanding of the life and death of stars. We will see that a star is a relatively simple physical machine, for which a surprisingly large number of properties can be estimated even with limited effort. Also the end states of stellar evolution (white dwarfs, neutron stars and black holes) can only be understood thanks deep insight from modern, (*i.e.*, 20th century physics.) The most important mathematical and physical techniques of the theory of stellar structure and evolution will be presented. Stars play a crucial role in large body of astronomical facts (*e.g.* distance of galaxies and the abundance of chemical elements therein) immensely important for a large number of fundamental discoveries in astrophysics (e.g. Hubble's Law, the Big Bang, Dark Matter, and the Accelerating Universe.) None of them would have been possible without knowing stellar properties!

Learning objectives:

On completion of the course, students should be able to:

- Understand how the basic stellar parameters are observationally determined,
- Be familiar with the physics of the internal structure of a main sequence star,
- Know how stars evolve from the main sequence, how they transmute the elements in their cores and how this relates to the history of the present universe,
- Understand the compact objects of the end states of stellar evolution - white dwarfs, neutron stars, black holes,
- Study the possible exotic astrophysical processes involving these compact objects.

Text: **compulsory**: An Introduction to Modern Astrophysics (Second Edition) by B. W. Carroll & D. A. Ostlie [CO]

Tentative Schedule

Week	Date	Topic	Source
1	8/22-24	Observed properties of stars. Continuous radiative flux from stars.	CO 3
2	9/29-31	Spectral line formation	CO 5
3	9/ 7	Excitation and ionization in astrophysical plasmas.	
		Observed H-R Diagram.	CO 8
4	9/12-14	Determination of stellar masses & radii	CO 7
5	9/19-21	Stellar Atmospheres. Analysis of absorption lines in stellar spectra	CO 9
6	9/26-28	Solar photosphere, chromosphere, corona, solar activity	CO 11
		FIRST MIDTERM EXAM: **Wednesday, Oct. 5**	
7	10/ 3 - 5	Stellar interiors (hydrostatic equilibrium, pressure equation of state)	CO 10.12
8	10/10-12	Stellar interiors (energy sources, transport, and thermodynamics)	CO 10.3-4
9	10/17-19	Stellar modeling (equilibrium & stability)	CO 10.5-6
10	10/24-26	Solar interior, post main-sequence stellar evolution of low mass stars	CO 10.1;13.1-2
11	10/31-11/2	Stellar pulsation	CO 14
		SECOND MIDTERM EXAM: **Wednesday, Nov. 9**	
12	11/ 7 - 9	Evolution of massive stars. End States I: White dwarfs	CO 13.3;15.1-5
13	11/14-16	End States II: Neutron stars, Black holes. Supernovae	CO 13.3;15.6-7
14	11/21	Evolution of close binary systems	CO 17
		Thanksgiving Recess: November 23-26	
15	11/28-30	Review	**handout**

FINAL EXAM, **Friday, December 9 2-4 p.m.**

Texts: Supplemental optional reading material

Not surprisingly, there is a wealth of books on the subject. A sequence of classic books illustrates the path of progress of the field. Among them, there are the following seminal texts

- Emden, *Gaskugeln*, 1907;
- Eddington, *The internal constitution of stars*, 1926;
- Chandrasekhar, *An introduction to the study of stellar structure*, 1939;
- Schwarzschild, *Structure and Evolution of Stars*, 1958;
- Clayton, *Principles of stellar evolution and nucleosynthesis*, 1968.

Less historical, but pedagogically useful are, *e.g.*

- Prialnik *Stellar Structure and Evolution*, (Second edition, 2009),
- Phillips *Physics of Stars, 1st (1990) or 2nd Edition (1999)*,
- Böhm-Vitense *Stellar Astrophysics: Vol. 1 Basic Stellar Observations and Data*,
- Böhm-Vitense *Stellar Astrophysics: Vol. 2 Stellar Atmospheres*,
- Böhm-Vitense *Stellar Astrophysics: Vol. 3 Stellar Structure and Evolution*,
- Kippenhahn & Weigert, *Stellar structure and evolution*, 1990 (Second Edition: 2012) (note that this text is on a considerably higher technical level than all the others!),

In the course of the semester, I will distribute photocopies (and provide files on blackboard) of relevant selection of some of these books (relying on the *fair-use copyright law for educational purposes*!)

In my opinion, Schwarzschild's is still the most beautiful book on the subject, despite the fact that it was written before the computer revolution spawned a wealth of numerical results of stellar evolution. I maintain that in no other text are the basic principles so clearly and economically explained.

Finally, my Danish friend and colleague J. Christensen-Dalsgaard (University of Aarhus) makes his own lecture notes freely available on the web:

`http://astro.phys.au.dk/~jcd/evolnotes/LN_stellar_structure.pdf`.

I recommend it as an excellent text on the subject. For your convenience, I will link it directly into blackboard.

Exams

There will be **two mid-term examinations** and one **final exam**. The overall **course grade** will be based upon examinations and homework as follows: the mid-term exams are **each** worth 25% of the total score of the course, the final exam is worth 35% the total score of the course. The remaining 15% of the total score are for homework.

Broadly speaking, grading is by the **distribution curve** of the combined scores of exams, homeworks and lab, following the tradition in the Department of Physics and Astronomy. In particular, please note that I do **not** use rigid percentage marks (such as, *e.g.*, a rule that 90% would correspond to an A- or similar). Further details about the grading procedure are **given in class**.

In the week before each exam I will **review the essential topics** and indicate which material could be on the test.

Homework

There are 7 homework sets

Homework # 1	given out:	Aug. 24	**DUE:**	**Sep. 7**
Homework # 2	given out:	Aug. 31	**DUE:**	**Sep. 14**
Homework # 3	given out:	Sep. 7	**DUE:**	**Sep. 21**
Homework # 4	given out:	Oct. 5	**DUE:**	**Oct. 19**
Homework # 5	given out:	Oct. 12	**DUE:**	**Oct. 26**
Homework # 6	given out:	Nov. 9	**DUE:**	**Nov. 28**
Homework # 7	given out:	Nov. 16	**DUE:**	**Nov. 30**

The most important thing to gain from homework is the development your own framework to solving problems. During the exams, there will be no one to help you. Those who miss the distribution in class can find the assignments on **Blackboard**, where I will also post solutions.

Homework can be turned in either during class, or be dropped into my mailbox on the 3rd floor of SHS (in the mail room opposite my office), or – if that room is closed – be slid underneath my office door (SHS 370). Since the homework solutions will appear on Blackboard immediately after the due dates, I am not able to accept late homework. However, you can miss one assignment provided all other scores are perfect according to the following policy:

While homework will count for 15% in the overall score, each of the 7 homework scores will be given equal weight, and each set with a perfect score will give 2.5%. I will cap the total homework score at 15%. This means that you can obtain the maximum homework score of 15% already with 6 perfect assignments. And you will have a possibility to "repair" deficiencies in individual scores by turning a 7th assignment!

You are encouraged to work together on the problem sets, go to the departmental TA office hours, and contact me in office hours or per email, but the final write-up must be your own.

USC-mandated communications

(i) Accommodation for students with disabilities

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.-5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

(ii) Academic Integrity

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. Scampus, the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: http://www.usc.edu/dept/publications/SCAMPUS/gov/. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: http://www.usc.edu/student-affairs/SJACS/.

(iii) Sexual harassment

Sexual harassment is a serious matter. Please see the information at the Sexual Assault Resource Center for the University of Southern California at https://sarc.usc.edu/reporting-options/ for guidance in dealing with these kind of issues. Contact phone numbers are: business hours: (213) 740-4900; after hours, call the on-call counselor at (213) 321-3982. You may also opt to contact the USC Center for Work and Family Life (213) 821-0800, http://www.usc.edu/programs/cwfl/). Both resources are confidential.