MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF PHYSICS
8.901 SPRING 2019
HTTP://WWW.MIT.EDU/~IANCROSS/8901_2019A/

INSTRUCTOR: PROF. IAN CROSSFIELD
GRADUATE TA: YU-CHIEN HUANG

PLANNED COURSE SYLLABUS AS OF FEBRUARY 5, 2019

This is the first half of a two-semester graduate-level sequence on astrophysics. Topics include: the Kepler problem, binary stars, gravitational waves, exoplanets; stellar structure and evolution; white dwarfs, neutron stars, and black holes; close binaries and accretion; the interstellar medium; radiative processes and astrophysical plasmas.

Our goal is to provide a foundation in astrophysics that will help you satisfy your curiosity, understand the scholarly literature, and embark on original research. The course is structured and paced to help astrophysics graduate students prepare for the astrophysics oral general examination.

We will assume a physics background equivalent to an MIT senior undergraduate physics major, including mechanics, electricity & magnetism, statistical mechanics, quantum mechanics, and relativity. No prior study of astrophysics is required. Although senior undergraduates are welcome in 8.901, we caution undergraduate students that the pace and workload of this class is substantially heavier than most undergraduate classes. Empirical data for the past 5 years shows that only about 1/3 of undergraduates who start this class complete it, and on average earn a grade a full letter grade lower than graduate students. Undergraduates are very strongly advised to consider coursework directly pitched to undergraduate physics majors, such as 8.282 (Introduction to Astronomy and Astrophysics) and 8.284 (Modern Astrophysics). 8.284 in particular covers much of the same material as both 8.901 and 8.902 (obviously not as in depth). A senior who has already taken 8.284 and is interested in going into greater depth may find that 8.901 is a good course to take on Junior/Senior P/D/F.

Crossfield's office hours will be by appointment. Since the course is directed to graduate students, we expect that you will do substantial research on your own before coming to course staff with questions (although short clarifying questions, or notification of mistakes, are always very very welcome).

Our textbook is *Astrophysics for Physicists*, by A. R. Choudhuri (Cambridge University Press, 2010). It can be accessed electronically via a link provided on the course web site, under "Materials / General" (MIT certificates required).

Lecture notes will be posted to the course website after the corresponding lecture.

Readings from Choudhuri will be supplemented by readings from papers and other texts which will be posted to the course's website during the semester. Some other potentially useful texts are:

- *Astrophysics in a Nutshell* by D. Maoz (Princeton University Press, 2007). A concise physics-oriented overview, similar to Choudhuri, but at a slightly more elementary level.
- *An Introduction to Modern Astrophysics* by B. W. Carroll and D. A. Ostlie, 2nd ed. (Addison-Wesley, 2007). The opposite of concise, with much more astronomical lore. Mostly comprehensive, though scant detail to some topics.
- *Theory of Stellar Structure and Evolution* by D. Prialnik, 2nd ed. (Cambridge University Press, 2010).
- *Radiative Processes in Astrophysics* by G. B. Rybicki & A. P. Lightman (Wiley-VCH, 2004). The standard graduate-level work on the subject.
- *Black Holes, White Dwarfs, and Neutron Stars* by S. L. Shapiro and S. A. Teukolsky (Wiley, 1983). Also a standard graduate text.

There will be one midterm, worth 15% of the total grade. It will be held on an evening close to Spring Break, with a precise date to be determined by class poll in late February or early March. Lecture will be cancelled the day after this exam.

Students will complete a ten-page review paper on a topic relevant to the course, worth 15% of the total grade. These papers will give you a chance to delve more deeply into one of the topics or questions covered in class, or on a subject closely related. In the course of summarizing the background, current status, and open questions in your topic of choice, I would like you to read and review several journal articles.

As part of the process, you will: choose a topic and submit it for approval by the end of February, submit an outline by the end of March, submit a rough but substantially complete draft by the end of April, and submit the completed paper on May 10.

There will be ten problem sets, each worth 5% of the total grade. Posting dates and due dates will be posted on the course calendar. Problem sets are to be handed in at the beginning of the lecture in which they are due, in the lecture classroom. *All problem sets must be completed to get full credit.* Lateness can only be accommodated **if notification of conflict or problem is provided in advance.** An email requesting extension sent at 1:00 am on the day the pset is due is not acceptable notice.

There will be a comprehensive, take-home final exam worth 20% of the total grade.

The text below gives the planned syllabus for 8.901 in Spring 2019. It will likely be updated from time to time to adjust depending on how well we cover the material that I am initially planning to cover.

- Week 1 (Feb 6 and 8): Introduction. Orders of magnitude, fundamental scales, distance measures. The Kepler two-body problem.
- Week 2 (February 11, 13, 15): Binary systems; gravitational waves from binary systems. Introduction to radiation. transport.
- Week 3 (February 18, 20, 22): Radiation transport; the Saha equation; stellar atmospheres.
- Week 4 (February 25, 27; March 1): Gray atmospheres; opacity and the H- ion. Timescales characterizing stellar processes and the equations of stellar structure.
- Week 5 (March 4, 6, 8): Order of magnitude analysis of stellar structure; scaling of stellar properties. Convective instability; polytropes.
- Week 6 (March 11, 13, 15): Nuclear burning; fusion pathways in the sun and other stars.
- Week 7 (March 18, 20, 22): Degeneracy pressure; stellar evolution.
- **SPRING BREAK** (Week of March 26)
- Week 8 (April 1, 3, 5): Wrap up of stellar evolution; end of stellar life, stellar remnants.
- Week 9 (April 8, 10, 12): Supernova energetics and observations; white dwarfs; neutron stars.
- Week 10 (April 15, 17, 19): Pulsars; black holes.
- Week 11 (April 22, 24, 26): Introduction to accretion; the Roche potential; the α-disk model.
- Week 12 (April 29, May 1, 3): Accretion continued. The interstellar medium; Jeans scale, ionization equilibrium.
- Week 13 (May 6, 8, 10): Ionization nebulae; supernova remnants. Beginnings of plasmas.
- Week 14 (May 13): Dispersion and dispersion measures; Faraday rotation. Magnetohydrodynamics.