ASTRON 331: Astrophysics (Spring 2016)

This course is a broad survey of several of the main concepts in modern astrophysics. The topics to be covered include the basics of stars and stellar evolution, star formation, the Milky Way and other galaxies. Time permitting, we will also cover the basics of cosmology. The course develops these astronomical concepts starting from undergraduate-level physics.

Instructor: Prof. Claude-André Faucher-Giguère
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Office: Tech F243
Office hour: TBD
Course website: http://galaxies.northwestern.edu/teaching (follow links).

To save trees, problem sets will be posted on the course web site. If you miss a lecture, be sure to monitor the course web page and ask your classmates about possible assignments.

Zach Hafen (Tech F224, ZacharyHafen2019@u.northwestern.edu) will be the grader for the course.

Time and location: Tuesday and Thursday, 2:00-3:20, in 2122 Sheridan, room 231.

Textbook (required): Astrophysics in a Nutshell by Dan Maoz. Princeton University Press (ISBN: 0691125848).

Other useful references: An Introduction to Modern Astrophysics (2nd Edition) by Bradley Carroll & Dale Ostlie. Addison-Wesley (ISBN: 0805304029).

We will follow Maoz's book and connect to topics of current research where appropriate. Carroll & Ostlie is a comprehensive reference that may be useful if you find the treatment in Maoz's book too concise.

Course pre-requisites: The course is targeted at advanced undergraduates. This course will assume a broad 300-level preparation in physics (classical mechanics, electrodynamics, statistical mechanics, and quantum mechanics). Specific concepts that should be familiar to students include the Kepler 2-body problem, the Doppler effect, basic hydrodynamics (e.g., hydrostatic balance), quantum tunneling, Pauli's exclusion principle, and the Maxwell-Boltzmann and Bose-Einstein/Fermi-Dirac distributions. Students who have not completed (or are simultaneously taking) all the relevant physics courses may enroll but may have to accept some results stated in the course. It's a small class, so we can adjust to make sure the level is appropriate. The best way to judge if your preparation is adequate is to look through Maoz's book and see if you can follow the derivations. Please also feel free to consult with the instructor. This course does not have a specific astronomy pre-requisite.

Course evaluation: Grades for the course will be determined as follows:

50% homework assignments
25% participation in paper discussions
25% final paper

For the homework assignments, you are welcome to discuss problems with other students, but you must write up your own solutions. Most homework problems will be based on those in Moaz' book and you will be asked to solve most (perhaps all) the problems for the chapters that we will cover during the term. For many problems, Maoz provides a short answer and your grade will be based on your solution rather than just your final answer. There will be at least 5 homework assignments but possibly more. Assignments will be due in class. Grades for late assignments will be automatically reduced by 20% and a further 10% will be deducted for each day late. Assignments turned in more than five days late will not be graded except under extraordinary circumstances.

We will take advantage of the small size of the class to make it as interactive as possible. Every other week, one lecture period will be devoted to a round table discussion of papers from the astrophysical literature on topics related to material covered in class. There will be typically one or two papers assigned for each discussion period, which I will choose to be relatively short and accessible. I welcome suggestions of papers or topics that students would like to discuss. The papers may be either "classics" of historical significance or exciting new results. I will expect all students to have read the assigned papers and be prepared to discuss the main results as a group. Since these papers will be drawn from the professional literature, you will not be expected to have understood all the details. These discussions should be both educational and fun, as they are intended to give you an opportunity to learn more about exciting astronomical discoveries. Your grade will be based on your level of participation.

Our paper discussions will be held on April 12, April 26, May 10, and May 24. For our first discussion, we will focus on exoplanets and discuss the following two papers:

- Mayor, M. & Queloz, D. 1995, "A Jupiter-mass companion to a solar-type star," Nature, 6555, 355. (First detection of an exoplanet around a main sequence star, using the radial velocity technique.)

- Batalha, N., 2014, "Exploring exoplanet populations with NASA's Kepler mission," Proceedings of the National Academy of Sciences, 111, 12647. (A review of the exoplanets census by the Kepler transit mission.)

The final part of your grade will be based on a written report. Your report topic can be based on any of the topics that we will cover in the lectures or in class discussions, but should go at least one step beyond what we covered in terms of explaining a new concept or discovery. Your paper should include quantitative elements, such as making use of some of the equations derived in class to explain a result. Your paper should be about 5 pages long (single spaced, including figures, equations, and references). Your final report should be emailed to the instructor as a PDF file and will be due on Monday, June 6.

Astrophysics papers can be downloaded through NASA Astrophysics Data System (ADS):

http://adsabs.harvard.edu/abstract_service.html. You may need to be on Northwestern's campus (or using a Northwestern VPN) to access papers published in some journals. Pre-prints are also typically available through the arXiv (astro-ph) system: http://arxiv.org/list/astro-ph/new.

Articles published in the *Science* and *Nature* journals are relatively short and written for a broad audience, so they are often well suited for our class discussions.

Topics to be covered: Observational techniques; basic observations of stars; the equations of stellar structure; nuclear energy production; radiative energy transport; convection; white dwarfs; supernovae; neutron stars; black holes; interacting binaries; star formation; HI regions; structure of the Milky Way; galaxy demographics; active galactic nuclei; groups and clusters of galaxies. Time permitting: Hubble's Law and the expanding Universe; cosmic microwave background; primordial nucleosynthesis and the origin of light elements.