Astro 16 – Astrophysics: Stars, ISM, and Galaxies
Fall 2017
Prof. David Cohen

Syllabus

This semester-long course is a survey of central topics in astrophysics, with an emphasis on stars, but also covering the interstellar medium (ISM) out of which stars are formed, and galaxies (including our own Milky Way) – large organized systems in which stars live their lives. We will introduce and/or review the underlying physics concepts (and mathematical techniques) necessary to understand the properties and functioning of stars, the interstellar medium, and galaxies. These include gravity, mechanics, thermal physics, and radiation (light) and matter (atomic physics), with a little bit of gas dynamics, statistical mechanics, and nuclear physics, too. We'll derive some key physical equations. Basic calculus will sometimes be used. We'll do a few integrals and solve a couple of simple differential equations by integrating them. The occasional derivative will need to be computed. Most important will be working to develop a sense of the correspondence between the math and the physical world of forces, matter, and energy.

Much of our study will be from a theoretical point of view (e.g. how do stars 'work'?) but a significant amount will be observational (e.g. how do we determine the properties of stars?).

We will all work hard to ensure that the class does not revolve around memorization of isolated facts, but rather involves developing integrated understanding of concepts (that then can be applied to different situations, systems, and problems). This will give students a bigger-picture view of stars and their lives from formation to death, cycling material through the galactic interstellar medium, producing heavy elements as well as light as a byproduct of their efforts to prevent gravitational collapse. It will also demonstrate how interesting physics concepts students have learned – or are learning – in other classes can be applied to real-world (if cosmic) systems, often in combination with each other.

Classes will include a fair amount of lecture, but also some discussion and in-class student work. Students will be expected to read about the material for a given day's class *ahead of time*, and sometimes to do a pre-class problem or two, based on that reading. Class itself will be for asking and answering questions and delving deeper into material that students will already be thinking about.

We will use a good textbook, "Foundations of Astrophysics" by Barbara Ryden and Bradley Peterson, lightly supplemented by other material. We will cover roughly one chapter per week. And we will have a homework assignment roughly once per week. (A subset of the homework problems will be graded, and students will be expected to look over the solutions to all the problems and make sure they can do all the problems, even the ones that aren't graded. There will be opportunities in class to discuss problems – and their solutions – from the previous week's homework.)

We will have four to six nighttime lab meetings (on Monday nights) roughly every other week, on a pre-determined schedule (see the syllabus, but note that due to cloudy weather, there may need to be a little rescheduling). Please leave Monday nights from 8pm to 11pm free. We will use the 24-inch telescope in the Peter van de Kamp Observatory on the roof of the science center for these labs, and when we work indoors, with data we've taken at the telescope, we'll do it in SC 187. Senior Laboratory Lecturer, Mary Ann Klassen and I will be running the labs together.

There will sometimes be additional reading from the textbook – on observational techniques and data analysis – (as well as lab manuals), assigned in preparation for the labs. And sometimes the nighttime lab sessions will be used to cover/review material, work on data taken previously (after all, we can only use the telescope when the skies are clear), or even to take midterm exams. Again, students should assume Monday nights from 8pm to 11pm will be occupied by Astro 16 activities, even if no lab is listed on the syllabus for that week, but ultimately a few of them will not be used.

Homework, pre-class problems, and lab work will count for a significant fraction of students' final grades (at least 50%), with two midterms (25% total) and a final exam (25%) composing the remainder.

Resources, information, and assignments (reading and homework, as well as labs) will be available primarily via the class website: astro.swarthmore.edu/astro16/ and Moodle will be used as a secondary repository.

I will accept homework up to 24 hours late and assess a 10% penalty; or up to 48 hours late with a 20% penalty. No permission needs to be asked; no excuses need to be given. If you have a true emergency, please get in touch with me. I will do whatever I can to accommodate you. Students will not be allowed to make up missed labs or exams. Please let me know if I seem unaware of religious holidays and observance that might prevent a student from handing in an assignment on time. I will be glad to accommodate religious observance.

If you believe that you need accommodations for a disability, please contact the Office of Student Disability Services (Parrish 113W) or email studentdisabilityservices@swarthmore.edu to arrange an appointment to discuss your needs. As appropriate, the Office will issue students with documented disabilities a formal Accommodations Letter. Since accommodations require early planning and are not retroactive, please contact the Office of Student Disability Services as soon as possible. For details about the accommodations process, visit the Student Disability Service Website at http://www.swarthmore.edu/academic-advising-support/welcome-to-student-disability-service. You are also welcome to contact me, Prof. Cohen, privately to discuss your academic needs. However, all disability-related accommodations must be arranged through the Office of Student Disability Services.

Topics and Readings
v.5 (3 Oct 2017), subject to change/updates, including particular lab nights

week 1:

sky position and motion characterization; angular measure
brief historical context of modern astronomy (Greeks, Kepler, Newton)
gravity, mechanics, uniform circular motion
Kepler's laws
virial theorem

[parts of Chs. 1, 2, & 3 of R&P, supplemented with a few pages of Bennett]

lab 1: basic use of telescope, camera, and filters [part of Ch. 6, handout on digital images]

week 2:

parallax
inverse square law
electromagnetic spectrum, light as wave and as photon
Doppler shift
spectroscopy, Kirchoff's laws

[beginning of Ch. 13, first half of Ch. 5]

week 3:

atomic processes, more spectroscopy
spectral line profiles
Maxwell-Boltzmann
LTE, Saha, Boltzmann, Planck

[rest of Ch. 5]

lab 2: image analysis

week 4:

pure absorption radiation transport, optical depth
solid angle
review, wrap-up, discussion

week 5:

stellar spectra (Eddington-Barbier)
magnitudes, colors, extinction and reddening

star properties: masses (binary stars), radii, temperatures

[rest of Ch. 13]

lab 3: independent observing for imaging lab

week 6:

hydrostatic equilibrium

[part of Ch. 7, begin Ch. 14]

fall break

week 7:

stellar atmospheres
spectral types
luminosity classes
Hertzsprung-Russell diagram

[rest of Ch. 14]

lab 3b: meeting to work on data and imaging

week 8:

stellar structure equations
energy sources and nuclear fusion
modeling and test of stellar structure

[Ch. 15]

lab time: midterm during Monday night lab period

week 9:

evidence for dust and gas in the ISM
absorption line diagnostics
H II regions
thermal balance

[Ch. 16]

lab 4: photometry and exoplanet transits

week 10:

star formation
post-main-sequence evolution
including supernovae
variable stars

[Ch. 17]

lab 5: exoplanets part 2

week 11:

white dwarfs
degeneracy pressure
neutron stars

[Ch. 18]

week 12:

Milky Way morphology
stellar populations
rotation curve and dark matter
central black hole

[Ch. 19]

week 13:

external galaxies
galaxy clusters
Hubble law

[Ch. 20]