# Astronomy 16 – Modern Astrophysics
# Fall 2009
# Prof. David Cohen

## Class Announcement

**Class meetings**: We will meet Wednesday afternoons from 1:30 to 4:00 in Cornell 110. We will also meet some Tuesday nights for lab, possibly staying at the telescope as late as midnight. We will have to be flexible about the dates we do our labs, as we are at the mercy of the weather.

**Material we will cover**: Astronomy, historically, is the study of the heavens (everything above the Earth's atmosphere). Astrophysics is a 20$^{th}$ century term that emphasizes the application of physics to the study of astronomical objects. All scientific study of the heavens today involves physics (and math, of course) in one way or another. In fact, the development of modern science itself was catalyzed by astronomy, around 1600, with the observational innovations of Tycho Brahe (the most precise observations possible, without a telescope), the theoretical innovations of Kepler (mathematical modeling of quantitative trends in Tycho's data on the orbit of Mars; he actually demanded that theory explain observations to within the errors!), the experimental innovations of Galileo (his invention of experimental science and his startling telescopic discoveries), and, finally, the synthesis of Newton (universal physical laws and physical models of causation). We will, unfortunately, not be doing any history of astronomy as such in this class, but I'll try to give the historical context for some of the facts and concepts we're learning.

Astronomy, as practiced before the 20$^{th}$ century, was primarily positional astronomy and classification – what types of objects are visible in the sky, where are they, and how do they move. Occasionally predictive, quantitative explanations were developed during the 17$^{th}$, 18$^{th}$, and 19$^{th}$ centuries; especially for the 'how do they move?' question. Ole Roemer's use of Jupiter's moons to determine that light has a finite speed and to measure that speed (accurately to within 30%), and the prediction and discovery of Neptune are two examples. But modern astrophysics was really born around the turn of the 20$^{th}$ century with the application of spectroscopy to stellar astronomy and the subsequent theoretical investigations of stellar structure. The intertwining of physics and astronomy was cemented in the 1930s with the discovery of the source of energy production in the center of stars – nuclear fusion. At the same time, astronomers were beginning to get a picture of the structure of our own galaxy, the gas and dust between the stars, and the universe as a whole. Soon after that, the invention of the radio telescope (an outgrowth of the development of radar during World War II) ushered in the era of non-optical astronomy – astronomy across the electromagnetic spectrum.

In our class this semester, we will focus on the application of quantitative physics to the understanding of astronomical phenomena. We will concentrate on stellar astrophysics, as it is the most mature subfield, with the most precise data (compared to, say, galaxies and distant cosmological objects) and with the most secure physical understanding of the key phenomena. But we will also study the interstellar medium, galaxies, and – if our pace and time permit – some cosmology. Stars and the processes they drive play integral roles in these other subfields, too.

Although a branch and application of physics, astrophysics is different than most other sciences in that it is rarely experimental – rather it is observational. It is more phenomenological than most other branches of physics, but the rich phenomenology can often be explained by relatively simple physical principles. There are many connections to specific physics topics, including gravitation, atomic physics, thermal physics, and dynamics, among others.

We will sometimes cover physics topics that you have not yet learned in physics class, and we will generally apply them and work to understand their key principles and effects even though we do not rigorously derive them from first principles. We will do a lot of algebra and calculus, but often make approximations and even order-of-magnitude estimates, with a goal of explaining the primary characteristics of the observed phenomena and their basic physical causes.

And we'll see the detective work required to learn anything at all about objects that are so remote from us. We'll see the beauty of the physical processes and objects in the universe; the incredible diversity of objects and phenomena that are produced by such a small number of physical principles and ingredients; the fact that nature is so complex and yet works so simply and automatically. And, finally, the connection between the physical universe and our short existence here in one small, strangely hospitable corner of the universe. One example of this is nucleosynthesis—the process by which new elements are made. The universe, when it began, contained hydrogen and helium (and a tiny amount of lithium). All heavier elements, including the calcium in our bones, the carbon, oxygen, and nitrogen in our tissues, and the iron in our hemoglobin, were made inside stars and then ejected back out into space, to be incorporated in a new generation of stars, planets, and, ultimately, us.

## Now for the practical stuff:

**Contact**: My office is SC 125 and I have official office hours from 11 to noon on Monday and 2:00 to 3:30 on Fridays. But I'm usually in my office (or lab across the hall) and if I'm not too busy, will be glad to talk with you most any time. Don't hesitate to send me email at night.

The class webpage (astro.swarthmore.edu/astro16) is a primary means for communication as well. All assignments, announcement, solutions, etc. will be posted there. (After a week, they are moved to the "old announcements" and "old assignments" sections, linked from the main page.) There are also links to useful information. I have also set up a Blackboard page for our class (which links to the class webpage).

You should check the website regularly; certainly at least every Friday and every Tuesday evening.

**Labs**: We will be using the new telescope – the Peter van de Kamp Observatory – on the roof of the Science Center, for our labs. We are still working some of the bugs out of the system…but we will probably start by doing some spectroscopy of stars, which the telescope can do pretty well right now. We may work in conjunction with Eric's Observational Astronomy seminar some nights.

We'll have to stay flexible about when we do our lab work, as it needs to be clear, of course (though after we get some data, there'll be some analysis we can do on the computer, indoors). I'd like to get started pretty soon – maybe September 8 – but the first time out we'll probably do mostly recreational astronomy to get you familiar with the telescope (and camera, filters, spectrograph…).

**Textbook**: We will be using Dan Maoz's *Astrophysics in a Nutshell* as our primary text. It is a very terse book, without a lot of descriptive detail. It is quite quantitative and mathematical. We will use our class time, homework problems, and other resources to supplement the text, but we will follow it closely.

You should print out and keep with your notes the list of typos and corrections in the textbook. You can find it linked from the "announcements" section of the class website.

I've put Ryden & Peterson's *Foundations of Astrophysics* on reserve in Cornell (along with a copy of our main text). The reserve shelf is an honors reserve shelf, which means it's not behind the front desk (it's actually very near the front door). Ryden & Peterson is a much larger, more thorough book. I recommend you consult it often, as you're doing the reading from Maoz and doing the problem sets. Also, I encourage you to use the web in general, Wikipedia in particular, and also Astronomy Picture of the Day (and its search capability and copious links). There are also useful reference books, like the *Encyclopedia of Astronomy and Astrophysics* (in the reference section of Cornell, not far from our class's reserve shelf) and also available online (see the class website).

The science librarian, Meg Spencer, has put together a page of astronomical resources for our class. Please check them out. It's linked from our class website as well.

**Grades, exams, etc.**: We will have one midterm (probably during the fifth week of the semester) and a final exam.

You'll notice below that homework counts for a significant portion of your final grade. There's really no excuse for not racking up the points on your homework assignments. I'm always happy to help and you should feel free to ask the astro majors in the junior and senior class for help. I strongly encourage you to work with each other on homework assignments, but, of course, the work you hand in should be your own. And it should be neat and clear and you should always label variables with units.

Labs, exams, and other out-of-class activities which are missed without prior permission will not be made up. You will get a zero if this happens. If you've got a conflict, scheduling problem, family emergency, etc., get in touch with me ahead of time and we'll make an arrangement.

I will not give extensions for problem sets. Assignments will be due in the class mailbox (mounted on the wall, to the left of my office door) generally by 5:00 PM on the due date. If it's in after 5:00 it will count as late. One time per semester I will accept a homework assignment that's later than 5:00 and not count it as late as long as it's in the mailbox when I arrive in the department the next morning.

I will accept late homework assignments, no questions asked and no excuses given, within two days of the due date, but you will be docked 20% of the total number of points for that assignment. Anything later than two days will also be accepted, but it will only be checked for completeness and given a flat 50%.

We will have homework assignments nearly every week. I plan to have them due on Monday, with some questions covering the previous week's material and some covering the upcoming week's material.

Your **final grade** will be based on the following breakdown:

Homework/problem sets 35%
Midterm 20%
Labs 15%
Final 30%

I reserve the right to make small modifications to this breakdown based, for example, on the number of labs we actually end up doing or problem sets we end up having. I will certainly let you know ahead of time if there are changes.

**Class time**: To be honest, I'm not exactly sure how things are going to go with such a small class, and the new textbook we're using. I think that I will lecture most of the time, elaborating and providing background to and extensions of the material in the textbook. We will certainly solve some problems together in class. I may ask you to present small amounts of material in class, and I certainly expect and will encourage participation in class – talking, questioning, problem solving. And we'll do some demonstrations, look at real data, and perhaps even read a research paper or two.