Syllabus for AST 2039, Spring Term 2003 - 2004
1. Overview

Astronomy has been re-vitalized by many discoveries and breakthroughs in understanding over the past 40 years. Just to mention a few items, we have neutron stars, black holes, stars being born, quasars, pulsars, mysterious bursts of gamma rays, and relic radiation from a hot early stage of the Universe. Some of these discoveries and breakthroughs are due to observatories in space, free of the Earth’s obscuring atmosphere, although other technologies (such as new radiation detectors and fast computers) also deserve much of the credit. The new information is continually brought to the public via the communications media, with PBS television programs being especially notable sources. Although many of those programs are excellent, they cannot answer questions that occur as you watch, nor can they provide discussions in which you can get involved. I encourage you to watch such programs, and to bring up in class any points of interest that fit in reasonably well with our course objectives.

AST 2039 is different from a typical undergraduate science course in several ways. You can expect to be stretched mentally. What that statement implies will become evident within the first few weeks, but briefly you will need to do the reading assignments before you come to class, and to think your way through them. We will discuss the readings, with main attention given to the logical developments presented by the authors. Do not hesitate to disagree with the authors’ viewpoints or with mine. Some parts of the reading material are beyond the 2000 level, but do not panic if you cannot cope with those parts - you are not responsible for everything in the readings. The way to find out which parts you are responsible for is to attend class. If we do not discuss it, you are not responsible for it. So focus on those parts you can understand, make notes on the parts you do not understand, and rely on the classroom discussions for clarifications. You will benefit properly from our classroom sessions only if you have already read the corresponding assignments. Here is what a former student wrote, in case you have problems initially:

"... it was quite delightful to find the dust clearing and knowledge seeping in. At first I believed the sections out of my league and was surprised to find I could do the work. Ego booster. Sizing up the Universe surely minimizes everyday problems."

2. Your Background

In order to cover 40 years of progress we will have to eliminate many topics that would be in a normal astronomy survey course. In particular, we will not have time to cover much about telescopes and other instruments, finding our way around the sky, characteristics of planets and other solar system objects, tides, precession, eclipses, celestial coordinates, and several other areas. As in the catalog, AST 2039 addresses "ideas concerning the origin, evolution, and future development of the Universe and its major constituents". Beginning about 1960, many of those ideas have been revolutionized.

Anonymous quote: "When you’re in a hockey game is no time to learn how to skate." How does that apply here? Read on: Understanding of the basics is necessary for appreciation of the great recent discoveries. Therefore the first four weeks will focus on such topics as atomic and molecular structure, scientific notation (for numbers), units in physics and astrophysics, the Doppler effect, brightness measurement, Newton’s laws, interactions of radiation and matter, spectra, and relativity. Many students will have picked up some subset of those topics in other courses, but do some background reading to cover any deficiencies. The material of the first four weeks is important as background for all the rest of the course. To go through the first four weeks without acquiring a solid understanding of the Doppler effect or the nature and usefulness of spectral lines (for example) is to be handicapped for the rest of the course. Although the course is essentially non-mathematical, you are expected to know high school mathematics such as working with fractions, exponents, and simple equations.

3. Learning how to learn

We hear of athletes who reach levels of achievement far beyond their natural talents, and we hear of others with great ability who never progress to high levels. Sometimes an athlete matures over the years and performs better as his or her physical skills diminish. The importance of know-how in such persons is obvious. In a similar way, a student can develop mental skills that make understanding easier, longer lasting, and more useful, but first it is necessary to appreciate certain overview points. Notice that the goal is understanding, not memorization. If memorization were the goal, courses would not be needed -
we could just take a list of facts and memorize them at home. A university is a place to learn how to think and learn how to learn. There are tricks and techniques for memorization, but they do not help in understanding. History has seen remarkable feats of memorization, such as remembering $\pi$ to thousands of digits, but the memorizers are often below average in using information and thinking independently. The next section will give some ideas on learning how to learn, but there are many more. For example, you could develop a mind-set where you put yourself in the place of the first person to come up with a concept. Imagine that you actually are that person and think through all the steps - reasons for being interested in the problem, having the basic ideas, testing them, refining them, etc. You may find it useful to think up little computational problems as you go along (yes, little ones - things you could do on a pocket calculator in a few keystrokes, or maybe without a calculator), and you may want to develop your own thoughts along these lines.

Another ingredient in good learning is realistic assessment of understanding. Briefly - don’t be too easily satisfied. Try to see concepts from more than one point of view and check whether they all make sense. A paradox is a disagreement between explanations that should agree in their logical consequences. Paradoxes are initially upsetting because they force us into the discomfort of knowing that we don’t understand. But paradoxes are our friends because they let us know when we go astray, hopefully before it’s too late. So if two ways of seeing into a problem lead to a contradiction, ask questions - first of yourself and then in class.

One day a student in my 9th grade science class was asked a question and had difficulty answering. After a few attempts, he said “well, I understand it but I can’t explain it”. The teacher responded with “let me tell you something from experience: if you can’t explain it, you don’t understand it” That remark shocked the class because the student’s excuse was a common thing to say. Over the years, I have grown to appreciate the teacher’s wisdom by asking, whenever in similar difficulty, whether language is the problem. The answer always comes back: no, I know the necessary words and I know enough rules of English to put them together. What I need is to understand this thing better. Yes, every time. Teacher was right.

4. Four Important Skills

Years of experience show that the performances of many students in beginning level astronomy courses can be greatly enhanced if they improve four basic skills. These are

1. Interpretation of graphs
2. Visualization
3. A sense for rough sizes and locations (orders of magnitude)
4. Understanding of proportionality

All four skills can be improved by practice, but your practice may need some guidance. The skills can help in other courses and throughout life. The following ideas should help:

4.1. Graphs

The first thing to do with a newly seen graph is to read the axis labels. A good habit is to do this immediately, even before you look at any plotted points or lines. Obviously there is no chance to understand a graph unless you know what is plotted. Next read the units on both axes and verify that they make sense (are consistent with the labels). Now look at the plot, but do something else as you look: Mentally “write” a concise sentence that describes the plot in simple language (imagine that your sentence is for someone who cannot see the graph). Finally, ask yourself “What is the point of the graph”?

4.2. Visualization

Ability to visualize objects and collections of objects in two and three dimensions is a skill that varies greatly from one person to another, but can be improved with practice and sincere effort. We will need only very simple visualizations in the course, but we will need those for sure. For such simple visualization, the main problem is unlikely to be lack of ability, but more often a lack of trying. We will have many pictures and diagrams that require visualization for proper understanding. If you are having trouble in this area, let me know. For a fun way to practice, listen to the old-time radio shows on the Sunday radio program “Theater of the Mind”. There is no TV picture - you have to ”see” the adventure by visualization.
4.3. Rough sizes, etc.

Much of the course is concerned with relative sizes and locations of astronomical objects. The important thing is what you take with you for ten, twenty, thirty, . . . years from now. Good memory of accurate numbers is unlikely and serves little purpose unless you will be a professional astronomer (and perhaps not even in that case). Therefore emphasis will be on overall perspective rather than memorization of numbers. You should acquire a sense for the sizes of galaxies, clusters of galaxies, and the scale of cosmology on the big end, and for the Solar System, distances between stars, and the internal parts of galaxies at the smaller end. As you read the assignments and in class, ask yourself: "Can I make a rough sketch of how things are arranged?", and then actually make such a sketch. Do not try to remember dimensions to several digits, but try not to be off by factors of ten or a hundred, and think about relative dimensions of related objects and separations.

4.4. Proportionality

We all have a sense for proportionality in everyday life. Unfortunately many students have trouble applying their good inner sense of proportionality when it comes to science. For example, suppose you are painting a room that has 800 square feet of wall area and you run out of paint when only 200 square feet have been painted. You used 1 gallon so far. How much paint should you buy to finish the job? I am sure that everyone can do this without being told the answer. Now change the problem so that it involves sizes and brightnesses of stars, perhaps related to a graph or an equation, and somehow the problem can look hard. This difficulty may arise from a lack of having learned the three ways to express proportionality and how those ways are connected. The three ways are:

1. In a graph: The graph of a proportional relationship is a straight line through the 0, 0 point (through the origin of the graph).

2. In an equation: The equation of a proportional relationship has the form \( A = KB \), where A and B are variables and K is a constant. A might represent paint in gallons and B might be wall area in square feet. Then K would be so many gallons per square foot.

3. In words: Example: A is proportional to B or "the amount of paint needed to cover a wall is proportional to the area of the wall".

Kind of simple, right? Would you believe that this notion causes study problems? The reason is that many students do not inter-relate the above ideas 1, 2, and 3. So draw some straight line graphs, write the corresponding equations, and express what you see in your own words. The benefits can be tremendous.

5. Compound Concepts

Suppose we are learning about the Doppler effect. (The Doppler effect is a good example because you may know something about it from another course, or at least have heard about it.) The Doppler effect may seem to be a single concept after we have a solid understanding, but actually several basic concepts have to be put together to understand the Doppler effect, so it really is a compound concept. Some of those basic concepts in question form are:

- What is wavelength? What is frequency?
- What is a spectrum? Can I explain the idea of a spectrum in more than one way? What quantities are naturally involved in discussing or using spectra?
- Why do we need spectral lines to measure Doppler shifts?

- What is a spectral line? What does one look like? How wide are typical lines? What are bright lines? What are dark lines? What does "continuum" mean in this context?

- How are spectra made in astronomy?
- What is a comparison spectrum? How is one made? What is its purpose? How is that purpose achieved?

- Do I understand relative motion?
- What is meant by a Doppler shift? How is it measured?

- How does it depend on those things, if at all?
- What are some major uses of the Doppler effect?

Etc., etc.

I will try to make clear as many of the separate concepts as can be squeezed into the lectures, but you are the person best qualified to put them together into unified (compound) concepts. You know how your mind works (each of us is different). One important way is to ask questions of yourself and try to answer
them. Questions should naturally occur as you read the assignments - a good sign, showing that your mind is active. If very few or even no questions occur to you, then try to develop more inquisitive and critical ways to study. Such ways will help in your academic work far beyond this course.

6. Normal stars?????

When you have completed AST 2039 you will know about many kinds of bizarre objects, but will have learned only a little about normal objects. Of course, this is a course in highlights and discoveries, and there is little time to cover things like normal stars in more than a perfunctory way. For proper perspective, we need to keep in mind that there are huge numbers of quite ordinary stars for every neutron star and many, many normal galaxies for every peculiar galaxy. The Astronomy Department has a wide range of courses that cover the main areas of modern astronomy. Perhaps the strange objects will inspire you to learn more about normal ones.

7. Attendance

The past several years have seen a major drop in undergraduate attendance. This observation is based not only on my sections, but on communications from other Astronomy and Physics professors as well. Accordingly I have begun taking attendance on most days - a practice that did not seem necessary before about 1997. I am mentioning this up front because there is not much point to preaching the benefits of good attendance later, with those who need the sermon not being there. It may be that the low attendance is connected with increased availability of class notes and course materials via the Internet, and resulting widespread confidence that satisfactory grades can be achieved without attending regularly. The reality is that there is an extremely strong correlation between attendance and grades in this course, and good attendance is a requirement for attaining an A or B+. There can be a good-attendance bonus for persons near the lower edge of the next higher grade.

8. Exam questions

Students often ask - usually late in the course - "how can I study so as to do well in the exams?" For best results I recommend that you read each of the booklet articles three times - once before we cover it in class (so your mind is prepared for the subject matter), once right after we cover it (to solidify what you’ve learned), and once just before the exam. You may be able to get by with less reading, but if you want a high grade, then it’s best to go with the recommendation. Of course you also should follow the hints in Sections 3 and 4 (above).

It might seem that multiple choice exams cannot test material such as the above-discussed items, but they can and will do so. Therefore if you focus on understanding and overall perspective, you should do well. If you focus on memorization - probably not.

9. Text Book(s)

The reading assignments can be purchased in a booklet of Xerox copies from Target Copy, 22 NW 13th St. The complete references are given below, so you can find the original articles in the library, but the booklet will be a convenience. Some of the original versions are much better than the booklet’s Xerox copies because their color illustrations do not copy very well in black and white. The booklet of readings is our text book and there is no additional required text. You will not need the booklet of readings until about the 4th or 5th week of class, and it probably will not be in the store much before that. However I mention an optional book that you might want to buy. The book is "Astronomy Today, Volume II - Stars and Galaxies" (4th Edition) by Chaisson and McMillan. The book is not required because your main need of it will be only in the first 4 weeks, because it is not the only such book that will do, and because it is fairly expensive. As an alternative to buying a copy, you may want to consult one or more of the basic astronomy text books in the library for background. If you already own a basic astronomy text book, I will be glad to examine it and estimate how useful it might be.

10. Classroom Participation

Be prepared for an interactive class. Please do not have negative feelings if your answer or comment is incorrect - we learn by jumping in and doing things, right or wrong. I may sometimes give an explanation if I disagree with your response - that is not to emphasize how wrong it is, but to make clear that the disagreement does have a reason behind it - it is not just arbitrary. It is difficult to give proper credit for participation in a large class, but I shall try. If you
have been participating and suspect that I might not remember your participation or know who you are, find some way to remind me - I want to raise your grade for such participation. There is no penalty for incorrect participation.

11. Exams

There will be three exams, which will be in multiple choice format and mainly not cumulative (the second and third exams involve only the material covered since the previous exam, with a few exceptions. The main exceptions are the basics of the first 4 weeks, which you will need throughout the course). You are allowed one disaster day, which means that the lowest of your three grades will be dropped automatically. There is only one make-up exam and it comes at the end of the course. The dropped exam makes make-ups unnecessary in all but exceptional circumstances. Only students who missed more than one exam are eligible for a make-up and only a proper written excuse from an appropriate person (such as an M.D.) qualifies one for a make-up. Written excuses must be provided at the earliest practical time. There is no separate final exam.

Some students are good at guessing correct responses to multiple choice questions from subtle clues in wording. Experience shows that technique not to work in this class. As an experiment, I gave two exams to such a person (one not taking the course, but with pride in ability to identify correct answers). The results were somewhat below the guessing level, in agreement with my impression from exams administered to regular students. The moral: if you want to do well, you will need to understand the course material (really!), which will require good attendance and regular preparation.

Here are some other techniques that will not work:

1. Memorizing exam answers from previous years.
   (Because this year’s questions will be new - I do not use old questions again.)
2. Memorizing a list of facts.
   (Because very few, if any, of the questions test factual knowledge. If there are four possible responses to a question, there will be four explanations, only one of which is as explained in class. Usually the other three options will be very clearly wrong.
3. Narrowing the choices by eliminating obviously silly responses that are intended only for amusement (there will not be any of those).

   You will be pleased to know that:
4. You do not have to be concerned about subtle variations in responses. All will be clearly different and the wrong ones will definitely be wrong.
5. There will be no "all of the above" or "none of the above" answers, which I consider unfair, nor ones such as "both a and b", and so on. One answer is right and the others are wrong.

The questions and answers will be longer than you are accustomed to. The reason is that they involve explanations, not facts. Explanations need more words than do facts.

If you are not doing well at some point in the term, read this syllabus again. You may find clues into the nature of the problem. Experience shows that the students who do well in AST 2039 mainly are those with a genuine interest in the subject matter. Those without such an interest can improve their performance by cultivating one as they go along. That should be easy - remember, it’s your Universe, and possibly the only one you will ever have.

12. Extra Help, Office Hours

Most students feel that they should see a professor only in desperate situations. However I have time to see you and you are welcome any time during office hours, which are Tuesday and Thursday from 3 to 5 PM. Occasionally something comes up and I cannot be here, but usually I will be around. If you want to come in at other times, make an appointment before or after class, or by telephone (392-2052, ext. 235). My office is 322 Bryant Space Science Bldg. My Email address is wilson@astro.ufl.edu.

13. References in Class Reading Booklet

"Binary Neutron Stars", Scientific American, May 1995, p.52
"Black Holes in Galactic Centers", Scientific American, Nov. 1990, p.56
"Evidence of Time Dilation Suggests that Gamma Bursters are Very Far Away", Physics Today, Apr. 1994, p.17
"High Redshift Absorption Lines Show Convincingly that Gamma Ray Bursters are Very Far Away", Physics Today, July 1997, p.17


14. Aftermath

When you have completed the course, I hope you will look back on it as a learning experience not only in astronomy but also in the nature and methods of science. Science is our most effective way of understanding and coping with nature and the modern technological world, and I try to present the material in a way that will help in other courses and in life beyond graduation. I especially value comments from students that are made 5 or more years after taking the course, when there has been time to see learning in perspective.

R. E. Wilson January 2, 2004