ASTRONOMY 100Lg: THE UNIVERSE

Spring 2004 **Tentative Schedule** Dr. Warner

Text: Freedman & Kaufmann - *Universe (***Sixth** *Edition)*

Date	Topic	Reading
Jan. 13 / 15	Introduction; Early Astronomy; Celestial Sphere	Ch. 1,2
Jan. 20 / 22	Precession; Time-keeping; Lunar Phases; Eclipses	Ch. 2,3; make notes
Jan. 27 / 29	Eclipses; The Astronomical Revolution; Gravity.	Ch. 3,4
Feb. 3 / 5	Gravity; Properties of Waves; Radiation.	Ch. 4,5
	FIRST MIDTERM EXAM: Tuesday, February 10 (Bring a No. 2 pencil)	
Feb. 10 / 12	Radiation (cont'd); Atoms & Spectroscopy.	Ch. 4,5
Feb. 17 / 19	Spectroscopy (cont'd); Telescopes; Solar System: Introduction.	Ch. 5,6,7
Feb. 24 / 26	The Solar System: General Principles; Planetary Atmospheres.	Ch. 7–17; make notes
Mar. 2 / 4	The Solar System: Orbits, Rings,Tides. Birth of the Solar System.	Ch. 7–17; make notes
	SECOND MIDTERM EXAM: Tuesday, March 9 (Bring a No. 2 pencil)	
Mar. 9 / 11	Comets, Meteorites, Asteroids. The Sun - Our Star.	Ch. 17,18
	SPRING BREAK: Monday, Mar. 15 – Friday, Mar. 19	
Mar. 23 / 25	Energy and Thermonuclear Fusion; Stellar Quantities.	Ch. 18, 19
Mar. 30/Apr. 1	The HR Diagram; Stellar Evolution.	Ch. 19,20; handout
Apr. 6 / 8	Stellar Evolution (cont'd); Death of Stars.	Ch. 21,22,23; handout
	THIRD MIDTERM EXAM: Tuesday, April 13 (Bring a No. 2 pencil)	
Apr. 13 / 15	Black Holes; Our Galaxy.	Ch. 24, 25; handout
Apr. 20 / 22	Galaxies and Cosmology.	Ch. 26,27,28
Apr. 27 / 29	Cosmology; The Early Universe.	Ch. 28,29

ALL STUDENTS (NO EXCEPTIONS) WILL TAKE THE
FINAL EXAM ON THURSDAY, MAY 6, 2:00 – 4:00 p.m.

Classes meet:	Lecture: TTh 12:00-1:50, SLH 200
	(**NOTE: Exams may be held in different rooms – this will be announced**)
Labs meet:	SGM 219
Office hours:	Nick Warner: classroom/SSC216D, TTh 2:15–3:30, and by appointment
	Jonah Hare – SGM 416, – Mo-Th 3:00-4:00PM.
Office/phone numbers:	Nick Warner: SSC 216D; 740-1146, Jonah Hare: SGM 416; 740-8889
TAs' office:	SGM 409, SGM 415; – hours to be announced.
e-mail:	Nick Warner: warner@usc.edu, Jonah Hare: hare@usc.edu

Course Structure and Philosophy

Welcome to *ASTR 100Lg: The Universe*. This course is about your origins taken on the grandest possible scale. It is my hope that by the end you will have a sense of where we are in the universe, and how we got here: Not only in terms of the evolution of the planets, galaxies and of the universe as a whole, but also in terms of the development of our knowledge and understanding of astronomy. As a result, the early part of the course will involve a considerable amount of the essential basic science, and most particularly physics, organized according to how it was discovered, or became relevant to astronomy. The last three sections of the course examine what we know about the universe (and how we know it) at progressively larger scales: starting with the solar system, we then move out to stars in our galaxy, thence to other galaxies and, finally, to the expansion of the universe as a whole.

As a general principle, I will try to focus on universal features rather than on individual local peculiarities. For example, I would rather you knew what you might find in other planetary systems around other stars than you knew the names of every single moon of every single planet in our solar system. It will still be essential to memorize a significant body of facts, but I will try to extract general themes from these facts and endeavor not to inflict you with the miseries of extensive rote learning.

This course has roughly four parts:

(i) What and how we learn from observation; essential physics, basic concepts, and early astronomy

(ii) The solar system

(iii) The birth, life and death of stars

(iv) Galaxies and the evolution of the universe

I wish to spend more time on (iii) and (iv) than is typical in more traditional "first courses" in astronomy. The concepts in this material are the more intriguing, and are not so easily digested without assistance. The cost of this choice is that we will only make a rather cursory study of the planets.

This course is designed specifically for the non-science major who has very little, if any, background in the sciences and mathematics. The course is non-mathematical by prerequisite, but you will have the pleasure of learning to perform some calculations that are very simple and will employ formulae that are easy to remember. You will note that formulae represent ideas, reflecting the fact that mathematics is the language of science. **For the nervous math-phobe:** In the first two or three lectures I will give you an idea of the level of mathematics that will be expected.

Textbook and Reading Assignments

The textbook is: Freedman & Kaufmann - *Universe (Sixth Edition)*

The **detailed syllabus pages** at the end of this document give the **compulsory material** for this course: it is explicitly defined through references to the textbook [chapters, sections, boxes, tables and figures]. The indications "**make notes**" and "**handouts**" refer to additional compulsory topics, for which the course material will probably differ significantly from the textbook.

Note: As a general policy the lecture will not cover everything that is in the assigned reading. I will expect you to do the reading: The lecture will tend focus on the more difficult concepts, and questions that may arise out of the reading. So *please* **try to do the assigned reading before the lecture.**

Starry Night: The Software

There is an **excellent** software package that comes with the text, and it has a free, though limited licence. **I urge you to install and register this software, and play with it.** You may actually find it fun. As guidance in your play, you might look at the end of each chapter in the book: There are exercises specifically for *Starry Night*. I will also hand out some *Starry Night* exercise sheets. These are intended as voluntary supplementary exercises, and not as mandatory homework, and so are not to be submitted for grading. The idea is to reinforce and supplement the material presented in lectures.

By way of further incentive, the first Lab session will be entirely based upon Starry Night. If you have difficulties using the program, your lab TA will be able to help you. I urge you to try to use it before the Lab because you will get more out of the Lab, and because you will be able to ask more precise questions of the TA's if you have problems.

There will also be one or two Starry Night exercises on the formal homework that you will ultimately submit for grading, and so it is at least a good idea to install, register and familiarize yourself with the Starry Night program. I do not anticipate that we will use *Starry Night* a great deal in the latter part of the course, but it will be of immense value in helping you to visualize things at least in the first three weeks of lectures.

Exams and grading

There will be three one-hour mid-term examinations and one two-hour final exam. Of the three mid-terms, only the scores of the two highest will be counted. The score of the lowest of the three will be dropped. The grade in the course will be based upon the examinations as follows: the **two** highest mid-term exams will each be worth 20% of the total grade and the final exam will be worth 25% of the total grade. (The remaining 35% of the total grade will be given based upon the homework (15%) and the Laboratory (20%). See below.) **All exams are closed book.**

In the class prior to each exam I will distribute a handout with a summary of the material to be tested.

The midterm exams will be held in class, but probably **NOT** in our usual classroom (SLH 200). **Note:** The dates for the midterms are **Tuesday, February 10, Tuesday, March 9** and **Tuesday, April 13**; locations for the midterms will be announced later.

Please note that the third mid-term exam can serve as a make-up exam for either of the first two exams. There will **not** be any other make-up exams. Any student missing two, or more, of the mid-terms, will get a grade of zero in whatever he/she misses.

Warnings: (i) You should view the mid-term policy as a safety-net, and not as an excuse to goof-off on the early mid-terms. A student who misses an early mid-term for inadequate reasons, and then misses a later mid-term for completely legitimate reasons will receive little sympathy. **(ii)** This course will be graded on a curve, and while the Labs and homework make up 35% of your grade, the class average on these items is typically very high (see below). This means that provided you complete the homework and the Labs, your ultimate grade will primarily depend upon your performance in the exams.

The final exam will be cumulative and will be held on **THURSDAY, MAY 6, 2:00 – 4:00 p.m.**.

Homework

There will be four homework sets, and they will be due in class on the Thursday of the week before each of the exams. While the graded homework will not be returned to you in time for the exams, solution sets will be made available in a timely manner. Those who wish, before the exams, to compare their own answers

with the solution sets are recommended to sharpen their memories or photocopy their homework submissions. The homework problems are intended to provide useful (but, by no means, comprehensive) preparation for the exams. Note, however, that the exams will be multiple choice questions while the homework will involve longer problems with more complicated answers. (Exams will be graded by machines, while the homework will be graded by humans.) Since the people in this class come from very different backgrounds, there will be some choice between sets of more quantitative and more qualitative problems.

Homework Schedule

Homework # 1	given out:	Tuesday, Jan. 27	**DUE:**	**Thursday, Feb. 5**
Homework # 2	given out:	Tuesday, Feb. 24	**DUE:**	**Thursday, Mar. 4**
Homework # 3	given out:	Tuesday, Mar. 30	**DUE:**	**Thursday, Apr. 8**
Homework # 4	given out:	Tuesday, Apr. 20	**DUE:**	**Thursday, Apr. 29**

For those who miss the distribution in class, the assignments will be available outside my office, SSC 216D. **They will also be posted on the web.**

Graded homework will be placed in the boxes under my name on the 4th floor of SGM. This should happen a week to ten days after you turn in the homework.

The homework will count for 15% in the overall grade. I will take the best three (out of four) of your homework grades, each of the three will be given equal weight: 5%. As with the mid-term policy, a student who misses an early homework for inadequate reasons, and then misses a later homework for completely legitimate reasons will receive little sympathy.

In doing your homework you are strongly encouraged to collaborate in solving the problems and discussing the issues, however **each student must write up/complete his/her own answers to each problem.** Direct copying of homework solutions is, of course, an academic integrity violation.

From prior experience it seems that I must add two further comments: (i) If you work closely with someone on the homework then close structural similarities are expected in some homework submissions, this is reasonable. However a word for word, item by item overlap is unacceptable. By all means work closely with others in understanding the homework, but write up your own answers independently. (ii) Direct, or nearly direct, copying without interpretation or exposition, of text from another source (particularly without attribution) is unacceptable.

I want to be convinced that you understand the material.

Warning: The homework is intended to help you prepare for the exams. The majority of questions will thus be fairly straightforward, and it will **not** be very difficult to obtain a very good homework grade provided you give yourself enough time to do it. (Average homework scores of those completing the homework are typically 85–90% of the maximum possible homework grade.) The down-side of this is that if you do not complete three homeworks, then your total grade will be 5, 10 or 15 points lower than it could have been (each homework is worth 5%). Four (4) points is typically about the difference between an A- and a B+ on the grade curve.

GETTING HELP

I urge you to ask as many questions as you like in lectures: if you don't understand, then the chances are that half the class does not understand either. It is of invaluable assistance to me to get any feedback from the audience, and so questions and constructive criticism are extremely welcome. You should not be concerned that your questions will interrupt the flow of the lecture: It is my job to worry about this. **So go ahead and ask your question.**

I have regular office hours and the TAs will have office hours as well: use them, and not just once before each exam.

Jonah Hare also has regular office hours, but these are **exclusively** for questions and arrangements concerning the Laboratory.

You may find it extremely beneficial to form study groups.

Electronic Information and the Grade Reporter

Hopefully, all of you possess some measure of "electronic literacy" – if not, now is a very good time to start.

First, the most effective way to contact me and Jonah Hare is via e-mail.

Secondly, the home-page for this course is http://physics.usc.edu/Classes/A100/. **On this page you can find links to copies of important course materials.** Such materials will include homework assignments, review sheets, old exams and, at the appropriate times, current homework and exam solutions.

Third, there is the **grade reporter**. This is an automated electronic mail service that will notify you of your current grades and will also advise you of any important course announcements, such as exam locations or changes in homework schedule. To use the grade reporter you need to do two things

- You must give me your e-mail address so as to register with the automated system (this is to protect your confidentiality). I will hand out a sign-up sheet for this early in the semester.

  The e-mail address that you give me needs to be a USC domain name (e.g. student@xxxxxxx.usc.edu), otherwise it is very unlikely to work. Microsoft mailers and things from aol.com usually fail because of their non-standard mail headers.

- Once you are duly registered on the database you simply send e-mail at any time, and as often as you like, to **astr100grades@usc.edu** (**NOT** to me or Jonah Hare). You can type anything you wish in the subject field and in the body of the message - it will all be ignored. The act of sending the message causes the system to generate reply mail to you with current available grades for your homework, midterms and final. It will also ultimately report your overall grade for the course.

Notes:

- **Important information** and announcements, like exam locations, will be appended to the bottom of the e-mail replies from the grade reporter. So do not just read your grades, **look at the end of the message as well.** Even if you are not registered with the database, you can still get these announcements from the grade-reporter.

- Do not send mail **to me** asking for your grades. Such messages will be ignored. However, if you have problems with the grade reporter then send me e-mail about the problem, preferably with a copy of the error message that the grade-reporter sent to you.

- **Use this service.** Sometimes (usually very rarely) we mislay someone's homework. If one goes astray then the grade-reporter is the most valuable tool for detecting such problems, so check it regularly. The grade reporter gets its data directly from the spread-sheets from which I will assemble your final grade.

Finally, there are some glorious photographs and rather useful stuff to be found at quite a number of web sites. I **highly recommend** a regular look at the **Astronomy Picture of the Day,** at:
http://antwrp.gsfc.nasa.gov/apod/astropix.html.

You might also try:

http://www.jpl.nasa.gov/	http://webhead.com/wwwvl/astronomy/
http://marvel.stsci.edu/top.html	http://oposite.stsci.edu/pubinfo/Pictures.html
http://ringside.arc.nasa.gov/	http://www.stsci.edu/EPA/Comet.html
http://seds.lpl.arizona.edu/	http://seds.lpl.arizona.edu/sl9/sl9.html
http://www.seds.org/	http://www.seds.org/messier/
http://www.skypub.com/	+ many more (use a search engine like Yahoo or Google)
http://ge-labs.usc.edu/	Your GE-labs homepage

LABORATORY

This course has a laboratory component, and you should have already signed up for one of the lab sessions. The purpose of these sessions is to give you some feeling for making and interpreting observations, thereby reinforcing some of the course material by direct experience. Indeed, without such experience some of the theoretical material will seem a little abstract. We also want you to get some hands-on experience in using a telescope: One often sees spectacular pictures from the large telescopes around the world, but we would like you to have a sense of what is possible from a small, but good "amateur" telescope.

Some of the labs will be directly related to the lecture material, and some (like the observation sessions) are intended as supplemental enrichment activities. We hope that the laboratory will enhance your experience and enjoyment of this course. Please appreciate the great logistical complexity of arranging laboratories for so many people with such a broad variety of backgrounds: we therefore ask for your good will and patience in this enterprise.

A detailed outline of the Laboratory component of this course may be found on the last page of this syllabus. Here I will merely underline some of the important details.

Important Notes:

(i) **The first Laboratory meeting for this class will be held in the week January 20 – 22.**

(ii) All questions about Laboratories and their organization should be addressed to your Lab TA, or to Jonah Hare. While we coordinate lab and lecture activities as far as we are able, Jonah Hare is the primary authority concerning labs.

(iii) In the Lab there is a very strong emphasis on participation and therefore, as with the homework, it is relatively easy to get a high grade: The class average in the Lab is also typically 80%– 90%. It is therefore very important to participate fully. Each Lab is worth about 4 points in your overall grade for the course, and as I indicated before, 4 points is typically the difference between a B+ and an A-. Also note that **you must pass the laboratory in order to pass the course overall**: If your Lab grade is 60% or below, you will fail the Lab and hence fail the course.

(iv) There are quite a number of carefully scheduled laboratory events, some of which are fixed by the structure of the universe. *(e.g. Dark sky trips cannot take place when the Moon is in the sky.)* Please read the Lab Schedule *carefully* and **take note of important dates.**

DETAILED SYLLABUS

The following pages contain a tentative plan of how the lecture material will be covered. This is meant as a guide, and not as a legally binding document. As the course evolves, we may deviate from this syllabus: We

will probably fall a little behind schedule, particularly after the midterms and in the discussion of the solar system. Therefore, from time to time I may delete, or shorten some parts of the syllabus. Having said this, you will see that I have indicated which sections of the book are pertinent to which week of the course. **Unless I instruct otherwise, you should take this to be the compulsory reading material for the course.** You will also benefit much more from the lectures if you have read it, or at least skimmed through it **before** you come to the class.

You will see that in some weeks we will cover an apparently insane amount of material (*e.g.* in weeks 7 and 8 we will cover about 11 chapters of the book). Obviously the corresponding reading assignment is a little unreasonable: at such points it will be important to take notes since I will give you a list of essential facts that you should dig out of the chapters, I will also give a overall synthesis of the ideas.

Some of the material that I will present in lectures will differ significantly from the textbook. I have endeavored to indicate when this will probably happen by putting the remark "**make notes**" in the syllabus. As a rule, if you see this in the syllabus, or if you see that the week covers a large number of chapters, then you should indeed **make notes**.

ASTRONOMY 100g - Detailed Syllabus

Note: You should make a habit it of reading all the "Boxes" and looking at all the tables and figures within a chapter. If I specifically mention a box, table or figure below then this is meant to indicate that the material is particularly important. "Lab" refers to the sections of the text that will be covered primarily in the laboratory sections.

1. Introduction
   (a) Why Astronomy (Essay p. 18)
   (b) Scientific Method and confidence in theories (1.1; **make notes**; Essay p. 42)
   (c) Quick Tour through our Universe (1.2,1.3,1.4,1.8)
   (d) Astronomical Quantities and Numbers (1.5,1.6,1.7; Boxes 1-1,1-2,1-3)
2. Celestial Sphere; Precession; The Calendar
   (a) Celestial Motions (Stars, Sun) (2.1,2.2,2.3,2.4)
   (b) Celestial Coordinates (Box 2-1)
   (c) Seasons (2.5; Figure 2-12)
   (d) Precession (2.6)
   (e) Time, Calendar (2.7, 2.8; Box 2-2)
3. The Moon, Eclipses & Early Astronomy
   (a) Lunar Phases (3.1; Box 3-1)
   (b) Lunar Months; Synchronous rotation (3.2)
   (c) Eclipses (3.3,3.4,3.5)
   (d) Ancient Distance Determinations (3.6)
   (e) Ancient Astronomy: Eclipse prediction (*optional*: Box 3-2)

4. The Astronomical Revolution

   (a) Motion of Planets: Geocentric Model (4.1)
   (b) Heliocentric Solar System: The Seed of the Astronomical Revolution (Copernicus) (4.2)
   (c) Galileo and the Telescope (4.3)
   (d) Brahe's Observations and Kepler's Laws (4.4,4.5; Box 4-2)
   (e) Newton's Laws (4.6; Box 4-3)
   (f) The Completion of the Astronomical Revolution:
   Newtonian Physics or "from Crystal Spheres to Matter Flying in Space" (4.7; **make notes.**; Box 4-4)

5. Radiation, Atoms & Spectroscopy

   (a) Waves in general, and Electromagnetic Waves in particular (5.2; **make notes.**)
   (b) Astronomy as Observational Science (The short introduction before 5.1, p. 92)
   (c) The Speed of Light (5.1)
   (d) Temperature and Radiation: Black Bodies (5.3, 5.4; Boxes: 5-1, 5-2, 5-3)
   (e) Wave-Particle Dualism (5.5)
   (f) Moving Sources: Speed of Light, Doppler Effect (5.9, Box 5-6)
   (g) Spectral Lines (5.6)
   (h) Introduction to Modern Atomic Theory (5.7)
   (i) Emission and Absorption Spectra (5.8)
   (j) Spectroscopy as a Fundamental Astronomical Tool (Box 5.5; **make notes.**)
   (k) Why is the Sky Blue, and Why are Sunsets Red? (Box 5-4)

6. Telescopes; Earth & Moon

   (a) Simple Optics and Telescopes (6.1,6.2) **Lab**
   (b) Need for Large Telescopes (6.2, 6.3; Box 6-1) **Lab**
   (c) Spectrographs (6.5) **Lab**
   (d) Radio Astronomy (6.6; Figure 6-27)
   (e) Improving Ground Based Astronomy (6.3, 6.7)
   (f) Importance of Different Parts of the Electromagnetic Spectrum (**make notes.**)
   (g) Earth: Overall (8.1; Table 8-1)
   (h) Earth: Interior (8.2)
   (i) Earth: Plate Tectonics: Past, Present and Future (8.3)
   (j) Earth: Atmosphere (8.5)
   (k) Moon: Overall (9.1; Table 9-1)
   (l) Moon: Surface; Craters and Maria (9.1)
   (m) Moon: Tides (4.8); Synchronous rotation (3.2)

7. Planets and Other Things in the Solar System

(a) Keeping the Essentials in Mind: General characteristics of planetary systems (**make notes.**)
(b) Overview of the Solar System (7.1; Box 7-1)
(c) Evolution of planetary atmospheres (**make notes**; Box 7-2)
(d) Mercury (Ch. 10)
(e) Venus (Ch. 11)
(f) Mars (Ch. 12)
(g) Jupiter & Moons (7.2, 7.3, 7.4; Ch. 13, Ch. 14)
(h) Saturn (Ch. 15)
(i) Uranus, Neptune, Pluto (Ch. 16)
(j) Tidal effects: Roche limit, Orbital Resonance, Clearing, Bodes Law and Chaos (**make notes**)
(k) Asteroids, Comets, Meteorites (7.5, Ch. 17)
(l) Dinosaur killers

8. Birth of the Solar System; The Sun - Our Star
   (a) Origins and formation of planetary systems (7.7, 7.8)
   (b) Planets orbiting other stars (7.9)
   (c) Properties of the Sun (Table 18-1)
   (d) The Nuclear Reactor inside the Sun (18.1; Box 18-1)
   (e) Modeling the Solar Interior; Heliosesimology (18.2, 18.3; Table 18-2)
   (f) Solar Neutrinos (18.4; Essay p. 418)
   (g) The Solar Surface (18.5,18.6,18.7)
   (h) Solar Activity and Cycle (18.8,18.9,18.10)
9. Stellar Quantities; HR Diagram (HRD); Binaries
   (a) Stellar Parallax, Distances and Motions (19.1; Box 19-1)
   (b) Stellar Luminosities (19.2; Box 19-2) **Lab**
   (c) The Magnitude Scale (19.3; Box 19-3)
   (d) Stellar Color & Temperature (19.4)
   (e) Stellar Classification: Spectral Type (19.5; Table 19-2)
   (f) Stellar Size (19.6; Box 19-4)
   (g) Stellar Classification: HR Diagram (19.7, 19.8; Figures 19-14 and 19-15 & Table 19-2)
   (h) Cosmic Distance Scale I: Spectroscopic Parallax (19.8; Box 19-2)
   (i) Binary Stars and Stellar Masses; Classification (19.9,19.10; Figure 19.22)
10. Stellar Evolution I
   (a) Interstellar Material (20.1,20.2; Box 20-1; **Lab** (Star-Party))
   (b) A Star is Born (20.3,20.4)
   (c) Early and Main-Sequence Evolution (First paragraph of 21.3; Table 21-1; Boxes 21-1, 21-2; **make notes.**)

(d) Evolution on and off the Main Sequence (21.1)
(e) Red Giants (21.2)
(f) Observational Tests: Star Clusters and Age (21.3)

11. Stellar Evolution II

(a) Pulsating Stars (21.5)
(b) End Phases of Stellar Evolution: White Dwarfs (22.1, 22.2, 22.3, 22.4; Table 22-1)
(c) End Phases of Stellar Evolution: Creation of Chemical Elements (22.5)
(d) End Phases of Stellar Evolution: Supernovae and Neutron Stars (22.6, 23.1, 23.2, 23.3,20.8, 22.9)
(e) Chandrasekhar limits: White dwarf, neutron star or black hole? (24.2, 24.3; **make notes.**)
(f) End Phases of Stellar Evolution: General (**make notes.**)
(g) End Phases: Black Holes (24.1, 24.2, 24.5, 24.7; **make notes.**)
(h) Optional: Evaporating Black Holes; Worm Holes (24.8; Box 24-3)

12. Our Galaxy.

(a) Our Galaxy: Location of the Sun (25.1, 25.2; Box 25-1)
(b) Cosmic Distance Scale II: Cepheids and other Variable Stars.
(c) Our Galaxy: Overall Picture and Rotation (25.3,25.4; Box 25-2)
(d) Flat Rotation Curves and Missing Mass (25.4; Figure 25-17)

13. Galaxies; The Large Scale Structure of the Universe

(a) The Discovery of Other Galaxies (26.1, 26.2)
(b) Local Group, Galactic Clusters and Superclusters (26.6)
(c) Distribution of Matter in the Universe, Gravitational Lenses (26.6, 26.8; Figures 25-17, 26-28)
(d) Cosmic Distance Scale III: Standard Candles (26.4)
(e) Hubble's Law and Ultimate Cosmic Distance Scale (26.5)
(f) Red-shifts and Look-back time (27.1)

14. Quasars, Active Galaxies (this topic may be treated only very briefly if time is limited)

(a) Quasars (p. 505; 27.1,27.2)
(b) Active Galaxies (27.3,27.4)
(c) Supermassive Black Holes (27.5)

15. Cosmology & Early Universe

(a) Olbers Paradox and the Expanding Universe (28.1, 28.2)
(b) Big Bang (28.3)
(c) Microwave Background Radiation (28.4)
(d) Temperature in the Early Universe (28.5)
(e) Abundance of Elements: Hydrogen and Helium (7.6, 28.4, 29.4)
(f) The Cosmological Constant, the Fate of the Universe and other issues in Cosmology (28.6,28.7, 28.8, 28.9; **make notes.**)
(g) The Very Early Universe (Ch. 29)