

AST 301 Spring 2009 Review for Exam 5

This exam covers all of stellar evolution, described in Chapters 19, 20, 21, and 22. Four thick chapters make for a very large amount of material, but in one way it may be easier to understand because it is unified by one theme—the story of a star’s birth (“star formation”), life (main sequence evolution), old age (red giant... asymptotic branch) and eventual death (white dwarf, supernova, perhaps gamma-ray burst, neutron star, black hole). Nearly all the material was covered in class, *except* that I will leave it to your discretion whether to read the sections describing the phenomena that can occur when stars evolve in binary systems (20.6, 21.1, and details of binary neutron stars in ch.22); however you will be *not* be tested on this material.

I strongly recommend that you try all the questions at the end of each chapter; they are nearly all good ones, at the level that will be typical on the exam. Some exceptions are listed below. As usual, ignore questions that involve calculations, and notice if a question is on a topic not on the exam (binary phenomena). I will, as usual, take a few of the exam questions from the end-of-chapter and online questions. However I do *not* recommend that you spend most of your study time trying to find the answers to these questions: they should be attempted after you have studied, as a self-test, although a quick look at them might be good to give you an idea of how much you understand.

A good way to review is to try to “tell the story” of the evolution of stars of different masses, starting with the main sequence phase, making sure you can explain all the stages of evolution and the differences between the evolution of low-mass and high-mass stars. Each time you use some new terminology, e.g. “degenerate core,” try to explain what you mean, as if you were explaining this to someone with no background. Try some really simple-sounding questions whose answers are not simple at all. For example, “What is the difference between a brown dwarf and a white dwarf?” As you explain how their similar-sounding names have little to do with anything they have in common, ask yourself if you understand the one basic property that they do have in common, and which controls their futures; and why are they called “white” and “brown”?

Another approach is contained in the notes that accompany the lecture slides. There the material is presented in a condensed way, skipping all details and irrelevant side stories, but in many cases including illustrations, not from your textbook, that I think may give you a more visual way of remembering the various phases of stellar evolution, or a visual guide for trying to tell the story yourself.

Here is a condensed summary of what I consider to be the most important features of each chapter. Suggested end of chapter questions, and excluded sections, are listed for each chapter.

Chapter 19.

Most of this material was covered in class, and will appear on the exam. Notice that sec.19.6 (the last section, on Star Clusters) is closely related to the next chapter, especially the technique for obtaining the ages of star clusters. This is extremely important in astronomy because it is one of the only ways that we can determine the ages of stars.. Probably the most important part to feel comfortable with is sec. 19.2, because it is similar to what you’ll be reading in the next chapter, using the H-R diagram to describe the evolution of stars. However you DON’T have to memorize the “stages” that the authors describe, not by number—i.e. I won’t ask you “In what stage does X occur?” I don’t care about the numbers, just that you understand something about the evolution, how a cloud becomes a protostar which becomes a main sequence star. Try to draw an evolutionary track for a protostar approaching the

main sequence. The same statements apply to the more advanced stages of evolution described in Ch. 20 and 21.

Ch. 19. Not on exam: Sec. 19.5 Shock Waves and Star Formation

End of chapter questions: R/D All except 14; TF/MC Not 7, 8, 20.

Chapter 20

The evolution of low-mass stars is the primary subject here, with a short discussion of the very different evolution of higher-mass stars once they evolve “off” the main sequence. You should be able to describe (e.g. how is its size, mass, luminosity, ... changing?) and explain the different phases of evolution that these stars go through, and what fuel they are burning and where.

What is the main sequence, and why do stars spend so much time there? Explain how stars try to rejuvenate themselves as red giants. Why do they eventually fail? How do they die? What is a planetary nebula--what do you expect to see at the center of it? Why can't stars below a certain critical mass become a star?

Although I urge you to read the sections describing the phenomena that can occur when stars evolve in binary systems (20.6, 21.1), you will not be tested on this material; the same goes for material on nova explosions in Ch. 21 and on binary neutron stars in Ch. 22 (22.3). Also remember that the section on star clusters at the end of chapter 20 (20.5) is closely related to the material from section 19.6 on the same subject.

Ch. 20. Not on exam: 20.6 (evolution of stars in binary star systems)

R/D All except 5, 10, 17, 19, 20; TF/MC Try them all.

Chapter 21

This chapter is about the very different late evolution and death of stars above a certain mass. There is a crucial phase at which the massive stars and low-mass stars (of Ch. 20) rapidly begin to evolve very differently. What happens? Why are the subsequent events of crucial importance in the formation of many of the chemical elements heavier than carbon? How do the other elements get produced? These massive stars end their lives as supernovae, amazingly powerful explosions in which most of the star is expelled into space; what will this expelled gas look like? What happens to material that doesn't get expelled? Try to explain the difference between a core-collapse supernova and a carbon detonation supernova, explaining the sequence of events that occur in each case. Attempt an explanation of how all the elements up to iron are cooked up inside of massive stars, with the abundances of the different elements partially set by what the explosion does to the “onion skin” structure of the envelope when the star explodes. Why does element production by nuclear fusion stop at iron? How is this related to the physical reason why cores collapse in supernovae of the same name? Can you explain several lines of evidence that massive stars really do explode as supernovae? Some have to do with the abundances of elements, others have to do with historically observed supernovae, supernova 1987A, and detection of pulsars, covered in the next chapter, at the centers of some supernova remnants.

Ch. 21. R/D All except 1, 2, 12; TF/MC Not 1, 2, 5, 11, 12.

Chapter 22

The subject here is primarily about what becomes of the central portions, the cores, of stars of different masses. Except for carbon detonation supernovae, which are believed to completely destroy the star without leaving any remnant at all, the other end states of stellar evolution are associated with different kinds of remnants—white dwarfs were already covered in Ch. 20. Here the remnants are **neutron stars and black holes**. Inbetween is a section on gamma-ray bursts, some of which may involve remnants (the inspiraling collision of a binary neutron star), but which may also represent “hypernovae,” presently the more favored theory.

Don't worry about "More Precisely" 22-2. And the material on binary neutron stars will not appear on the exam. Besides that, study it all, but remember to try to get the main ideas and how they are related. We don't care much about names and other details.

A few exceptions are the "famous" objects: You probably already know about Supernova 1987A, but here you should learn more detail about the Crab Nebula, and the object known as Cygnus X-1.

As with Chapter 21, a good way to review Chapter 22 is to try to "tell the story" of the evolution of stars of different masses, this time starting with the red giant phase, when the helium has burned to carbon in the core, making sure you can explain all the events that occur after that. Each time you use some new terminology, e.g. "neutron degenerate core," try to explain what you mean, as if you were explaining this to someone with no background.

Sample questions are on next page.

Here are some sample questions to find if you are prepared to take the exam. As usual, most of these tend to be a little more difficult than the average exam question.

1. What distinguishes a protostar from its earlier stage as a collapsing interstellar cloud?
 - a) Hydrogen begins to fuse.
 - b) It stops emitting infrared radiation and produces visible light.
 - c) Its central region becomes opaque and begins to heat up.
 - d) It is at that point near the main sequence.

2. What characteristic of a star cluster is used to determine its age?
 - a. The number of red giants.
 - b. The number of main sequence stars.
 - c. The faintest stars seen in the cluster.
 - d. The extent of the main sequence in the H-R diagram.

3. What effect does a magnetic field have on the process of stellar birth?
 - a) It speeds it up.
 - b) It causes fragmentation.
 - c) It heats the cloud.
 - d) It opposes the collapse of the cloud.

4. How was the chemical composition of the sun different 3 billion years ago from what it is now?
 - a. more hydrogen now
 - b. more helium now
 - c. more heavy elements now
 - d. it won't change until the sun becomes a red giant

5. When a star evolves from the main sequence to the red giant phase
 - a. the core gets hotter and the luminosity increases.
 - b. the core gets cooler and the surface gets hotter.
 - c. the core gets hotter and the luminosity decreases.
 - d. the core and the surface both get cooler.

6. Roughly how long does it take a stellar iron core to collapse?
 - a) One second.
 - b) One year.
 - c) A few million years.
 - d) Forever.

7. What kind of evidence identifies the Crab Nebula with the supernova explosion recorded by the Chinese nearly a thousand years ago?
 - a) Enhanced abundances of metals in the gas
 - b) A faint binary companion with a period that agrees with the time since the recorded event.
 - c) **Doppler shifts of spectral emission lines from the gas.**
 - d) Discovery of the pulsar at the center of the nebula

8. Most properties of a neutron star are extreme in comparison to normal stars. Which of the following properties is **not** unusual when compared to a normal star?
 - a. **mass**
 - b. rotation
 - c. magnetic field
 - d. density

9. The masses of neutron stars (not the original mass of their progenitor)
 - a. must be at least 8 solar masses.
 - b. must be at least 1.4 solar masses.
 - c. are only known for those neutron stars in binary systems.
 - d. are only known for neutron stars that are also white dwarfs.

[Hint: Think about why the masses of white dwarfs must be less than the Chandrasekhar limit.]

10. For an object falling into a black hole, which of the following would be seen by a distant observer?
 - a. The object would get brighter the closer it got to the black hole.
 - b. Time would speed up as it got closer to the black hole.
 - c. Light emitted by the object would increasingly redshift as it got closer to the black hole.
 - d. The object would begin to flicker.

11. The key to identifying a black hole candidate, rather than some other type of stellar remnant, in a binary star system is (there is only one correct answer):
 - a) one of the two stars cannot be seen
 - b) the unseen companion in the system must have a sufficiently high mass
 - c) the system must be a strong source of x-ray emission.
 - d) the seen companion must be an evolving main sequence or giant star
 - e) there must be evidence for a very hot accretion disk.

