Study Guide for Exam 3, Ast 309N (47760), Fall 2012 (Dinerstein)

Exam 3 will be Thurs., Dec. 6. It will have the same format as all earlier exams, but will be focused on the material covered since Exam 2, picking up with further aspects of white dwarfs and neutron stars, particularly in interacting binary systems, and continuing on to black holes, gamma-ray bursts, and gravitational lensing. While there are only a few scattered pages in Kaler's "Extreme Stars" on these topics, they are covered in considerable detail in chs. 3 – 5 and 9 – 11 in Wheeler's "Cosmic Catastrophes." Below is a brief outline of the topics discussed in the last third of the semester, with dates of the relevant lectures and assignments, **key terms and concepts,** and study questions. There will also be the usual office hours and help session during the week of Dec. 3 – 7.

Topic	Class Dates	Cards	Reading
I. Interacting Binary Stars	11/13, 20	11/27	Kaler, pp. 155-161, 167-8 Wheeler, ch. 3, 4, 5, 6.6, 8.6

General Principles: Roche lobes, inner Lagrangian point L_1, mass transfer, the Algol paradox, accretion disk, matter stream, hot spot

Interacting binaries containing white dwarfs: cataclysmic variables, what is a classical nova, what is a Type Ia = "thermonuclear" = "white dwarf" supernova

Interacting binaries containing neutron stars: hotter accretion disks (than for white dwarfs), X-ray emission from the accretion disk, making millisecond pulsars

II. Black Holes	11/27, 29; 12/4	11/13, 20, 27	Kaler, pp. 168-170 Wheeler, ch. 9, 10, 11

Basic Principles and Structure: escape velocity, event horizon, Schwarzschild radius, singularity, tidal forces near a black hole, spaghettification, "black holes have no hair," rotating black holes and the ergosphere, Hawking radiation

General relativity = Einstein's theory of gravity, curved space, embedding diagrams (rubber-sheet diagrams), gravitational bending of light, gravitational time dilation, gravitational redshift, relativistic effects when approaching the event horizon

Black hole (or neutron stars) in X-ray binary systems: Hercules X-1, SS 433, Cygnus X-1, relativistic jets

Gamma-Ray Bursts: discovery by the Vela satellites, long vs. short-duration GRBs, gamma-ray "beaming," NASA's SWIFT satellite, collapsars (birth of black holes), merging neutron star binaries, gravitational waves

Study Questions (*not* guaranteed to cover all possible questions on the exam!)

1. What is the significance of the *Roche lobes* in a binary star system? Under what circumstances does a Roche lobe correspond to the actual surface of a star?
2. Why is it said that Algol, consisting of a red giant and a Main Sequence star that has a larger mass than the red giant, is a “paradox”? How can we explain/resolve the paradox?
3. Specify, describe, and sketch the components of a binary star system in which mass is currently being transferred from a red giant to a white dwarf. What kind of emission (radiation) does each object in the system produce?
4. What happens to matter that passes through the inner Lagrangian point of a binary star system, and why? How does the latter depend on the nature of the star that is receiving the mass?
5. There are several types of outbursts/explosions that can occur in a binary system that contains a white dwarf that is accreting material. Identify these events by name, explain what happens in each, and compare the outcomes for these different events.
6. What differences might you expect to find for the accretion disk around a neutron star as compared to an accretion disk around a white dwarf?
7. Why is matter accreting onto a neutron star in an interacting binary star able – in at least some cases – to speed up the rotation rate of the neutron star? How might we see the result of this?
8. What is the significance of the event horizon of a black hole? of the singularity? How does the structure of a black hole change if it is rapidly rotating?
9. Roughly what are the sizes of the radii of white dwarfs and neutron stars, and the event horizon of a black hole? Which sizes increase as the mass increase? Which of them decrease?
10. Discuss the origin and effects of tidal forces near a compact star – in a region where the gravity is relatively strong and is changing rapidly with radial distance from the center.
11. How does Einstein’s way of describing gravity differ from Newton’s theory? What different behavior do they predict for light (photons) traveling through a region near a large mass?
12. Describe two (or three) relativistic effects that start to become noticeable, even dramatic, as you approach the event horizon of a black hole. (“relativistic” means that they are predicted by Einstein’s theory of general relativity, a theory about how gravity behaves)
13. How might you be able to tell whether an X-ray binary system contains a neutron star or whether it harbors a black hole? What evidence is needed in order to settle this definitively?
14. How was the gamma-ray burst (GRB) phenomenon first discovered? What properties of these events made them hard to explain?
15. What is the “collapsar” theory for the “long-duration” (100 seconds, vs. a couple of seconds) GRBs? What do we think is produced in these events?
16. What do we think is the explanation for the “short-duration” GRBs, and how might future measurements confirm (or disprove) this idea?
17. What is “Hawking radiation” and how does it change the mass of a black hole?