AST309L Fall 08-Scalo
REVIEW SHEET FOR 1st EXAM

The major topic for this exam is habitability, especially the "habitable zone," even though we will have only taken two lectures for it. This material is covered in sections 10.1-10.4 and 11.1 in your textbook. We will not go further than sec. 11.1, and postpone sections on detection of exoplanets and their properties to the next exam. There is also assorted material in chapters 12, 1, 2, and 3 as detailed on a handout you should have already downloaded (under "Reading" at website). The rest of the material consists of parts of chapters 12 (Drake equation), 1, 2, and 3, as detailed in the reading list handout. See also below for a few topics not on the exam.

The general problem that is being posed for this exam, and for most of the entire course is: If we think there is a chance that we might be able to detect signatures of life, or even intelligent life, on planets orbiting other stars, we will be using some sort of telescope, but how do we decide what stars we should "look" at? Out of thousands of stars of various types in the solar neighborhood, how can we narrow down the list? We will only have time to monitor about a hundred stars at most. If we detect planets that are even roughly like the mass of the Earth, how would we know which ones might be most likely to be "habitable" in terms of liquid water and other factors? That is the main focus, the arguments for thinking that life might be common, and reasons that could leave us pessimistic about any such search for extraterrestrial life. Examples of the latter are: If life depended on having a planet whose rotation was stabilized by a large moon like ours, or if the habitable zone in our solar system, as controlled by climate effects, only extended from 0.95AU to 1.05AU (if you don't understand why this would make habitable planets unlikely, you should begin studying now!). So part of your task is to understand why there are these inner and outer limits to the habitable zone, how they depend on a planet's properties, how the HZ probably varies with time in our solar system, and why the HZ will be at other distances from different types of stars.

There are four pdfs of lecture slides at the web site.

We covered all of the Sept. 2 and Sept. 4 sets of slides, except for the last few slides on Kepler's and Newton's laws. *I decided not to include any material on Kepler and Newton on the exam.* Also remember that I will not test you on the material about the nature of science or what gravity "really" is, even though these are interesting topics. The first part of that slide set *was* discussed in detail (concerning the elements probably essential for life as we can imagine it), and has several points not covered in your textbook, so be sure to review them.

We did not cover the slides for Sept. 9 in class—these are on light, and on using spectral lines to learn that moderately complex organic molecules are not as uncommon as we might have guessed. Look them over yourself—it is mostly review except for the examples of molecular line spectra from star-forming clouds. There isn't anything specific to memorize here. THERE IS ALSO AN ASSIGNMENT at the bottom of the fourth-from-last slide. I'll repeat it here, since I am likely to ask you about it on the exam:

Assignment 1: *Have any amino acids been detected in space? Begin by trying Wiki with "glycine". Is this up to date? Has glycine been discovered in space yet? Have any other amino acids been found? (Not "components of amino acids" or "upper limits", which means a non-detection, but a positive detection of an amino acid.) You don't have to know its name, but is it an amino acid used by life on Earth? Where was it detected? You will have to go further than Wiki to find the answer.* Hint—the discovery was made this year.

Slides from 9/11 and 9/16: This single long pdf file has 36 slides, but ignore 34-36 (I meant to extract them). It covers the major topic of the exam, "Habitable Planets," chapters 10.1-10.4, and 11.1. The ways in which distance from star, star's luminosity, and especially climate effects, determine a planet's temperature are especially important, so don't forget to take advantage of the Tutorial at the textbook web site on "Surface temperature of terrestrial planets."

There is also a second "Assignment" near the end of that file, which I'll copy here—it is likely I will ask you about it on the exam. It is related to material near the end of the slides on the types of stars we should search for habitable planets.

Assignment 2: *In March 2007 astronomers were surprised to discover that protoplanetary disks exist around binary star systems. Using the "Links" in your textbook web site, find out what telescope was used to make this discovery. What is it about this telescope that makes it perfect for detecting disks?*

You will find the background material for this question in the "Links" for ""Stars and Habitable Planets" at the textbook web site.

It is convenient to divide up the questions on the exam into the following areas, remembering that there will only be about 3-5 questions for most of them, but more for habitable planets and star systems.
A. "Galactic neighborhood," having to do mostly with distances, to the nearest stars, across our Galaxy, etc. (all in light years); you should also know the age of the Sun, the age of the Galaxy, and (very roughly) the number of stars in the Galaxy.
B. Drake equation. Remember you don't have to "solve" the equation, just be familiar with how the number of stars having planets, or planets with life, or with intelligent life, consists of a series of probabilities which, when multiplied together, can give an extremely small number. Also understand why the duration of life on a planet, or of a communicating civilization, is so crucial to what is implied by the equation.
C. "General background" – this is a catch-all for your reading in chapters 1, 2, 3, and covers the main questions of astrobiology as in ch.1 of your textbook, how common or uncommon the basic building blocks for life are (elements and molecules—we covered this in detail in class: see lecture pdf), Kepler's and Newton's laws are *not* on the exam, but basics about light are (only 2-3 questions). These are in a lecture pdf that I did not cover in class, but are also in your textbook.
D. An important topic that I will ask you to read about, but do not have time to lecture on, is the description of the basic features of objects in our solar system and theory for the origin of the solar system and other planetary systems in sec. 3.3 (pages 70-79). There will be a number of questions on the exam covering this, mostly the planet formation theory—Figures 19, 20, and especially 21 illustrate all the essential points. For basics about our solar system, you might try the tutorial "A virtual tour of the solar system" at the textbook web site, if you haven't already.
E. For habitability (10.1-4, 11.1): You should be able to describe the conditions that we think may be necessary in order for a planet to be conducive to life, and why—a list will not do. There are several considerations, including distance from star, climate effects, mass of planet, thick atmosphere, type of parent star (and several sub-considerations for each of these). Try to describe in words the differences between Venus, Earth, Mars as a way of understanding the inner and outer bounds of the habitable zone. If you are not comfortable explaining this, or anything else, in words, you have relied too heavily on memorization of key terms or phrases, and are unlikely to do very well on the exam, which assumes everyone knows the words. The exam tries to find if you are comfortable enough with what you have read that you will recognize it when it is in other words, possibly even everyday language. Do not be deceived by whether a possible answer "looks" correct or incorrect. A correct answer might be "Too big." An incorrect answer may be some statement that sounds just technical enough, like "The planetary mass is so large that it could not retain an atmosphere," or could even be a correct statement that nevertheless is not the correct answer to the question.

Your textbook's website has only a very brief blurb on habitable zone, although the discussion in the textbook (and in class notes) is extensive. If you are interested in further details or other work in this direction, go to astrobiology.com and type in 'habitable zone' in the search space—you will get a google-like list of popular-level press releases about this topic. However the discussion in the textbook and the the pictures and notes in the lecture slides should be all you need for the exam, and I would put off the extra resources until after the exam, just to make sure you don't get contradictory statements.

I include below a number of review questions below that covers the basic material. (These will be sent later if you are seeing this in an email on Monday afternoon.) The review questions at the end of the textbook chapters are very useful (see reading and lecture list for which ones to try), as are the "Think About It…" exercises scattered through the text. The more of these you think about and try to answer, the better you will do on the exam and the better you will understand the material, but I realize this depends on how much time you have to study, and how interested you are. I recommend that you start looking through these questions now, to get a feel for the level of familiarity and understanding you will need in order to do well on the exam. Sample multiple choice questions very similar to those you'll see on the exam are also given on this review sheet.

If you have questions about this material, please feel free to call me at 478-2748 or 471-6446, any time between 9am and 9pm. However do not call and ask for answers to any of the review questions below—those are for you to test your preparedness.

Some review questions. Be sure you can give clear, and in some cases concise, answers. Some of these are similar to questions occurring on the exam, although they will be encountered in the form of multiple-choice questions.

1. Think of an example from everyday experience that illustrates the concept of "contingency." Try the same for "convergence," and notice how much more difficult it is to think of examples.

2. Think about the factors in the Drake equation representing the fraction of stars with planets and the number per star that are habitable. State a circumstance that could make this factor one in a million, and explain why that is an example of contingency.

By now you should see that the entire Drake equation is nothing but the question "How convergent or contingent is the development of complex planetary life?"

3. If you were to send a signal at the speed of light to a civilization all the way across our Galaxy, about how long would it take? (e.g. A century? A million years? A billion? You just need to be able to give a rough number like this.)

4. What are the factors that are important in estimating the number of communicating civilizations in our Galaxy ("N" in the Drake equation)?

5. In descriptive terms, how is N related to the average distance to the nearest communicating civilization? In other words, if N is very small, or very large, how will the average distance change?

6. If you lived on a planet orbiting some other star in our Galaxy, what would likely be the distance, on average, to the nearest star?

7. Why do we think that planets are necessary for life? (There are two reasons that come to mind…)

8. What are the main four elements on which on which terrestrial life seems to depend? How were they produced in the universe?

9. What is the main importance of hydrogen for life? Oxygen? Hint: the answer is the same in both cases.

10. Nitrogen plays an unusual role for the existence of organisms on Earth. Explain. (Not in text)

11. Explain some of the special properties of carbon that might explain why life (at least on Earth) is based on this element. Name some astronomical environments in which reasonably complex carbon molecules have been found, and explain why this is an optimistic sign for the prevalence of life in the univese.

12. Why is infrared radiation expected to be the dominant kind of radiation emitted by planets and by protoplanetary disks? What if you wanted to observe the very outer regions of disks, or detect the Oort cloud of comets—would you look for longer- or shorter- wavelength radiation?

13. Before there was any observational evidence for disks around stars as the site of planet formation, why was it so strongly believed that planets form in such disks, rather than some other kind of geometry (e.g. spheres instead of disks).

14. What is the evidence for disks around young stars? Why might this suggest that planets are forming or will form there?

15. What physical processes are thought to be responsible for forming protostellar disks? For converting disk material into planets?

16. Describe how the phase (gas, liquid, solid) depends on temperature. Can you explain the direction of this dependence on the basis of the internal structure of each phase?

17. Explain why we think our solar system ended up with rocky worlds in its inner regions and icy or gaseous worlds in its outer regions.

18. Explain the concept of a liquid water habitable zone. What determines (a) its distance from the star, and (b) its inner and outer limits?

19. How was the solar system's habitable zone different when the Earth was young?

20. Explain one way in which an object's orbit might be in the habitable zone but the object is not habitable. Give an example in our solar system.

21. Explain one way in which an object outside the habitable zone could be habitable. Give a solar system example.

22. What conditions would be necessary to have a habitable planet not associated with a star, a "rogue planet"? (Your textbook discusses this.)

23. How does planet size (mass) influence whether a planet has a thick atmosphere? Besides size (and distance from star), what other factor might also influence whether a planet has a thick atmosphere?

24. What is the runaway greenhouse effect in terms that anyone could understand.

25. Explain what might be the habitability problem(s) for planets orbiting stars much more massive than the sun, binary star systems, or extremely old stars.

26. Why might a massive moon like Earth's moon be necessary for life**?** [It's not just tides—see ch.10] Why would this make life unlikely for planets orbiting extrasolar planets?

B. Sample multiple choice questions.

Here are some sample questions to give you a feel for what the exam questions will be like. These questions may or may not be on the exam, or appear in different form. They are meant for you to see if you have studied sufficiently—if you have trouble with them, then you need to study more. I recommend that you do not try to find the answers to these questions if you haven't yet nearly completed your studying—you will be wasting time looking for answers or discussing them with others, time better spent trying to better-understand the material. For the same reason, it is a waste of time to discuss these with classmates—if you have to ask someone, then you need to study more or call me.

1. If the average lifetime of a communicating extraterrestrial civilization ("L" in the Drake equation) is 100 years, which of the following is most likely to be true? (Read carefully!)

a. The number of such civilizations in our galaxy may be as large as a hundred thousand (10^5) or more.

b. There may be thousands, or even millions, of extraterrestrial civilizations presently in our galaxy, but it is unlikely that we could locate them by their signals.

c. We are probably the only planet in our galaxy with life.

d. There are probably no other planets in our galaxy with communicating civilizations.

2. Besides having surfaces, what is a fundamental reason we think that planets are necessary for life?

a. They can have temperatures in the range that seems necessary for the complex chemistry needed for life.
b. Planets are expected to have very long lifetimes, giving enough time for life to arise.
c. Planets do not emit ultraviolet light (like the sun and other stars) that would break the bonds of molecules attempting to form.
d. You could only have liquid water on a planet.

3. Which of the following gases could only condense to solid form in the outer solar nebula?

a. water, methane, ammonia ices b. metals like iron
c. mineral rocks d. hydrogen and helium

4. What is the major physical process that should cause the material around young stars to form a disk, rather than, say, a sphere?

a. outflows and jets from the newly formed star b. gravity
c. collisions between small dust grains d. rotation

5. What primarily determines the location of a star's continuously habitable zone?

a. the size of the planet and its distance from the star b. the temperature of the star
c. the stability of the star's brightness d. the luminosity of the star

6. The surface of Venus is very hot, *much* hotter than was expected. What is the crucial difference between the evolution of Venus and Earth which explains the huge temperature difference between the two planets?

a. Venus had a lot more volcanic activity than Earth.
b. Venus was too warm for the water vapor to turn into liquid form.
c. Venus was formed with, or produced, a lot more carbon dioxide, a greenhouse gas, in its atmosphere.
d. Venus does not have a large moon like the Earth's.

7. According to most calculations, Mars is in the habitable zone of the Sun, but is not habitable. How can this be?

a. Mars probably did have liquid water on its surface in the past, but its molecules were broken up by high-energy particles from the Sun due to the lack of thick atmosphere.
b. Mars probably once had an atmosphere with plentiful carbon dioxide clouds, which reflected more light than accounted for in the usual habitable zone calculations.
c. Mars is too small to retain an atmosphere necessary for liquid water to be stable.
d. Mars underwent a runaway glaciation in which surface ice increased the albedo (reflects more light), which cooled it further, leading to more ice, etc.

8. Your textbook discusses the possibility of isolated or runaway planets ("free-floating Earths") that have been ejected from the protoplanetary disk from which they formed. What condition is necessary that these runaway or "rogue" planets could be habitable?

a. They must derive enough surface heating by volcanic eruptions.

b. Tidal heating must be available if they are to attain liquid water temperatures without heat from a star.

c. They must generate internal heat for a long time, and they must retain a thick gaseous hydrogen atmosphere.

d. They must occasionally pass near enough to stars along their path that they can be temporarily heated.

9. One reason that might be valid for not expecting life on a planet orbiting a very high-mass (blue, spectral type O) star is

a. no habitable zone possible—star is too hot.
b. habitable zone too far from the star.
c. the lifetime of the star is probably too short for life to begin.
d. too much ultraviolet radiation.
e. no habitable zone possible—star is too luminous.