Astronomy 4

Section 1 (M through F, 8:30–9:20 am)

*Are you studying for something **other** than Test 1? Click the tab (above) for your upcoming test.*
*Note that the page numbers given in these tabs are for the **8th edition** of the Seeds / Backman text. (9th-edition pages are in parentheses.)*

Here are the chapters for Test 1, in the order that we covered them:

Chapter 1 (Overview of our place in the universe)
Chapter 2 (What we see in the sky, and basic motions of the Earth)
Chapter 3 (Moon's motions, phases, and eclipses)
Chapter 4 (Astronomy through Tycho and Kepler)
Chapter 5 (the part about Newton's laws of motion)

Chapter 1: Here and Now

Section 1-2 does a `cosmic zoom-out' starting with a person sitting on a bench. What do Seeds and Backman mean by the *field of view* in Figures 1-2 through 1-13? Notice that the field of view in Figs. 1-2 through 1-13 are given as distances. (Jumping ahead to Chap. 2 for a moment, astronomers also talk about a related concept called **angular distance**, which is covered on p. 19 (same page in both editions), in Chapter 2. Make sure you're clear on what we mean by the **angular size** of an object in the sky, or the angular distance between two objects in the sky. What are the units of angular distance?)

As we zoom out through Figure 1-6, we encounter a term called an **astronomical unit**. This is a very important term that we'll use over and over in this course. It's a basic `distance-measuring unit' in the solar system. Make sure that you understand what an astronomical unit is. Seeds gives some measurements using numbers, but it's most important for you to be able to understand it in words, in terms of the distance between the Earth and the Sun.

What is the **Solar System**? Is our solar system (the one that contains the Sun and the Earth) the *only* solar system?

What's a **light-year**? This is another very important distance unit. Here are some things to be clear about when it comes to light-years:

- Which is bigger - an astronomical unit or a light-year?
- Is a light-year a unit of *time* or *distance*?
- What is the definition of a light-year, in words?
- Here's a tougher question - how are an astronomical unit and a light-year related to each other? (Hint: How are they both related to the Earth?)

What's a **galaxy**? What do we call the one we live in? Make sure you understand the difference between a galaxy, the solar system, and the **universe**. (Seeds and Backman point out on p. 6 that people often have a Common Misconception about this.)

There are some things to know about the scientific method from Chapter 1---these are covered in `How Do We Know' 1-1. For example, after a scientists makes a **hypothesis**, what do they have to *do* to that hypothesis? (Hint: They use evidence to do it.)

Chapter 2: The Sky

In this chapter, we learned about what the sky looks like from here on the Earth, how it appears to move, and what's really behind these motions. We'll also learn something about how bright things look, which turns out to be a major concept in astronomy.

What's a **constellation**? Have all cultures throughout history thought up the *same* constellations? What's the official definition of a constellation, according to the IAU? How many of them are there? What's the difference between a *constellation* and an **asterism**?

How are Greek letters used to `name' stars? Are those `name a star' things that you hear about on the radio legitimate?

Now we get to an important, but tricky, subject---the magnitude system. Here are some things to make sure you remember, understand, and can explain:

- What does the **apparent visual magnitude** of a star or planet mean?
- Does a star with an apparent visual magnitude of 1 look *brighter* or *dimmer* to

the eye than a star with an apparent visual magnitude of 2? (Hint: Think about the analogy between `1st magnitude' and `1st class'.)

- What's the apparent visual magnitude of the *dimmest* stars visible to the unaided eye?
- Make sure you understand the definition of **flux** on p. 16 (same page in both editions).
- What's the ratio of flux between two stars that are 1 magnitude apart?
- What's the ratio of flux between two stars that are 5 magnitudes apart?
- EXTRA CREDIT: Be able to solve problems using the two equations on p. 16.

What's a **scientific model**? Can a physical model be used as part of a scientific model? (How Do We Know 2-1)

Now for another big, fundamental topic---the **Celestial Sphere** (see p. . I'll also talk about `The Two-Sphere Universe', although you won't find that exact term in the textbook\footnote (This term is from a classic book about astronomy called *The Copernican Revolution* by Thomas Kuhn, published in 1957. I highly recommend this for anyone who wants to do further reading; there's a copy in the De Anza Library.) We'll spend a lot of time talking about the celestial sphere, and we'll probably use the planetarium to do this.

Make sure you understand the 3 concepts and 16 italicized terms on the left half of p. 17 (right half of p. 17 in the 9th ed.). (If you have some extra time, you might want to play around with the free programs Stellarium and Celestia.)The `Sky Around You' spread on p. 18-19 is a big, important illustration for this topic, along with your notes and visual memories from the planetarium.

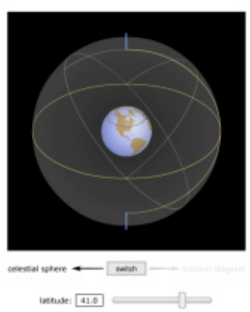
Here are some details that we (hopefully) went over in the planetarium:

- Make sure you understand the idea of the **cardinal points** (also called the `*four directions*' by Seeds and Backman on p. 17): **north point**, **south point**, **east point**, **west point**.
- Make sure you understand the idea of the **celestial sphere**. This is a very visual idea, so it can be tricky. Is it a real sphere? Or just a model? Make sure to carefully study the diagram in the upper-right corner of p. 18.
- What *direction* does the celestial sphere appear to rotate around the Earth? Does it really rotate in this direction? What's *actually* rotating?
- What are the **horizon**, **zenith**, and the **nadir**? (In addition to describing them in words, imagine standing outside under a clear night sky and pointing them out to a fellow observer.)
- What are the **celestial poles** and the **celestial equator**?
- What's the importance of your **latitude** on how the sky looks and how it appears to move? (If we had enough time, we might have used the planetarium to travel to the southern hemisphere. How did the sky look different from there?)
- Where would you have to be on the Earth in order to see the *whole sky* during the course of a year? (Hint: Look carefully at the drawings on the right side of p. 19.

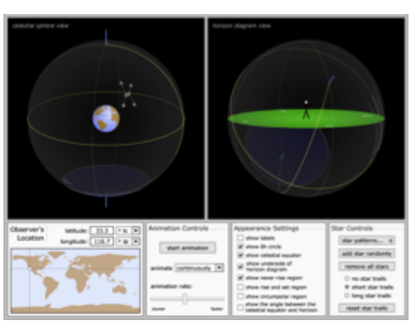
- I mentioned this earlier, but how are **angular distances** measured on the sky? Are units like *miles* used? What sorts of units are *really* used? Know the difference between a degree, an (arc)minute, and an (arc)second.

To help you understand all of these concepts, it's useful to "play" with them when you're not in the Planetarium. One way to do that is to download and play with programs like Stellarium and Celestia. Those programs take a little time to learn, however, so you may find it easier to "play" with the following simulations, which were made by the amazing folks in Astronomy Education at the University of Nebraska-Lincoln. They've made some really great simulations, and you'll see links to many of them as you scroll down on this page. When you see an `image link' to one of the simulations, I recommend right-clicking it and selecting `Open In New Tab'. That way, you can click back and forth between this list, which your'e reading right now, and the animation.

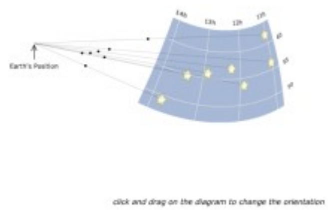
To get you started, try playing with this simulation, which will help you understand the difference between what we called the `Snow-Globe Universe' and the `Two-Sphere Universe'. First, drag to rotate the model around, and look at it from different directions. Then hit `Switch'. Then Switch back. Then move the slider, hit `switch', and so on.



Next, here's their simulation of the diurnal motion. There are a ton of great features in this one, and you can really learn a lot about how the rotating Earth makes it look like the sky is rotating! If I can ever find the time, I'd love to write a `how-to guide' for this simulator, and post it in the class's blog section. For now, I just recommend playing around with this one:



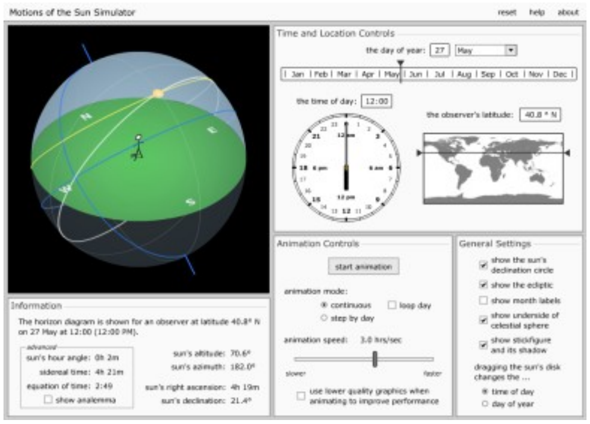
Here's a simple one, but a good one - a simulation of the Big Dipper, showing how the stars are **actually** scattered through space, even though they **seem** to be `attached' to a sphere (drag-rotate the model):



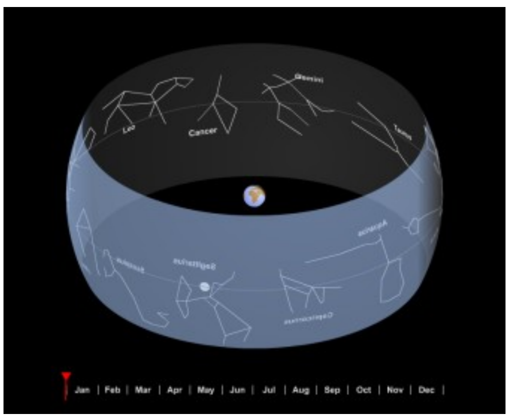
Next, we get to the `Cycles of the Sun' (p. 21). (It's called "Sun and Planets" in the 9th ed., and also stars on p. 21.) Here are some things to know about the Sun's apparent motion in the sky:

- What's the difference between **rotation** and **revolution**?
- What causes day and night? (Hint: Study Fig. 2.8.)
- How does the Sun *appear* to move through the sky during the year? What's really moving? (Carefully study Figure 2.9. This is the kind of thing that would make a great *concept sketch* question for Test 1, and/or the Final Exam. If you can re-draw Figure 2.9 and add labels explaining what's going on, that would be a great skill to have.)
- What is the **ecliptic**? What do we mean when we talk about the *plane* of the ecliptic? (Hint: How is the word `ecliptic' related to eclipses? Also, we *might* have used an analogy between part of the Infinum projector and this concept.)

Again, the good folks at UNL have made some nice simulations for this. To start, here's one that shows the Sun's apparent motion through the sky. Like the celestial sphere simulator, this has a lot of controls, and can get a bit confusing. But, if you play around with it enough, it can really help you get a handle on the motions of the Sun. (Don't forget that, like most of their simulations, you can drag-rotate the model to look at it from different directions.) If you find it too detailed or confusing, though, it's okay to focus on studying the book's section on `Cycles of the Sun' on p. 21. (It's called "Sun and Planets" in the 9th ed., and also stars on p. 21.)



Here's a simulation of the ecliptic. Drag-rotate this one, to look at it from different directions. Also play with the slider, to see where the Sun `appears' at different times of year. (As always, opening it in a new tab is handy.)

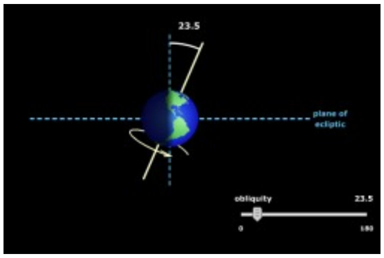


Now, we get to yet another big chunk of visualization. We probably spent a lot of time in the planetarium on this one, too. This is the topic of the **seasons**. Here are some things to know about seasons:

- What do we mean when we say that the Earth's axis is tilted 23 degrees from the plane of the ecliptic?
- What is the Common Misconception that most people have as to the cause of the seasons?
- What's the *real* cause of the seasons? (See the spread on p. 24-25.) Being able to make one or more diagrams like the ones on p. 24-25 would be another good example of a
- Make sure you understand the terms **solstice** and **equinox**. At what time of year does the noon Sun appear to pass *highest* in the sky? How about *lowest*?

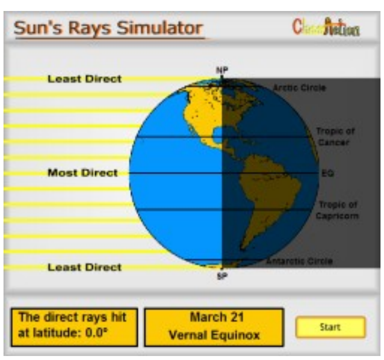
(Pages 24 and 25 are the same in both editions - a two-page spread on "The Cycle of the Seasons".)

You guessed it, there are some good UNL simulations to help you understand the seasons. The first simulation, shown below, is a good starting point. Open it in a new tab, and drag the slider to see what `obliquity' means:

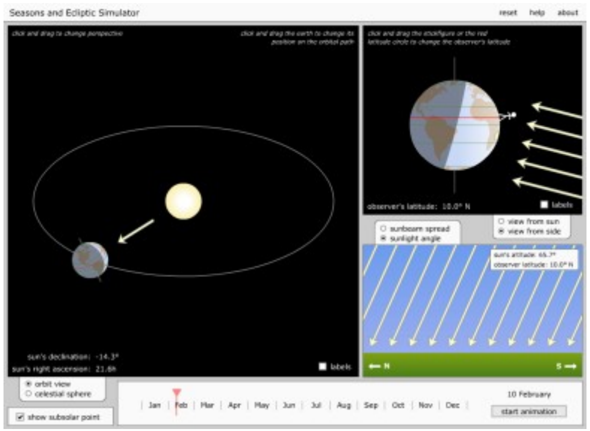


Another important concept, which we've used when talking about the celestial sphere, and when talking about the seasons, is **latitude.** Use this simulation to see what latitude is. Open it in a new tab, and drag the observer's location around on the globe (and shift-click to rotate the globe). The observer's latitude is the blue coordinate.

Next, play the animation in the following simulation, Notice how the angle of the Sun's rays changes from season to season. Compare this to p. 24-25:



Finally, for the brave-hearted, try UNL's Seasons Simulator. This is another big one, with lots of controls, but if you invest the time, you can really visualize and `internalize' what's going on as the seasons change:



What's the **zodiac**, and what's its relationship to the ecliptic? What do astronomers mean when they call astrology a **pseudoscience**? (See `How Do We Know 2-2)

What is **precession**? We might or might not have had time to cover this in the planetarium, but it's covered on p. 17 of the textbook, and also Figure 2-7 on p. 20. (p. 17 and 18, and p. 21, in the 9th ed.) If we could live for many thousands of years, what would we see in the sky? What's really happening (hint: it has to do with the Earth's rotational axis.) How long does is a cycle of precession? What effect does this have on the locations of the celestial poles?

Chapter 3: Cycles of the Moon

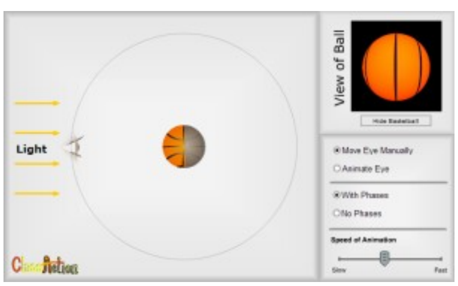
What is the difference between the **nearside** and the **farside** of the Moon? Why is there this difference? (This isn't really discussed until chapter 21, but I will probably talk about it in class before Test 1, at least briefly. It is briefly shown in diagram 1 in the upper-right corner of p. 34, or p. 36 in the 9th edition.))

Does the Earth's shadow cause the **phases** of the Moon, or is this merely a common misunderstanding?

How does the Moon's phase change from day to day, and why? It will be worth studying Section 3-1 (starting on p. 33 (p. 34 in the 9th edition)) and the two-page spread `The Phases of the Moon' (on p. 34-35 (9th ed.: p. 36-37)) in detail. We probably made at least one detailed drawing of the phases of the Moon, similar to diagram 2 on p. 34 (p. 36 in the 9th ed.). Being able to redraw diagrams like this, with good explanations, would be a great skill to have. We probably also made some drawings that I called `phase drawings'. They showed the direction of the Sun's rays, as well as the direction of our line of sight, and the **terminator** and the *nearside/farside boundary*. These drawings also included an `as seen from Earth' view. If we made drawings like this in class (and we probably did), there is value in being able to do this on your own. This might seem strange for a multiple-choice test, on which you won't have to actually **draw** this stuff. But if you have the ability to **make** such a drawing, I think it will help you figure out the deeper multiple-choice questions.

Now for the UNL simulations of the Moon's phases… I recommend starting with this one, to test your knowledge of the phases and their names:

Next, it's good to reinforce your understanding of how a spherical object can show phases if it's lit up from different directions. We did this in the Planetarium when I turned on a bright light at the back of the room and shone it on the Infinium projector ball. This `basketball' simulation will allow you to practice the same idea. (Tips: As always, right-click and open it in a new tab if you can. I like to `Move Eye Manually'. And remember all that stuff about "Is this the <u>left</u> side of the nearside or the <u>right</u> side of the nearside? Think about that while you play with this simulation.)

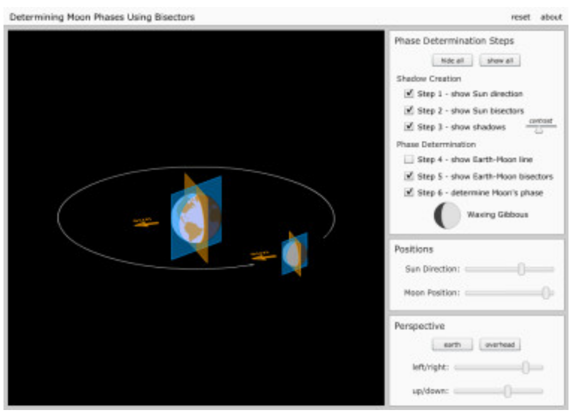


A little ways above, in this list, I reminded you about the "phase drawings" we made in class. Like I said, these are great things to practice. The next UNL simulation is very similar to our phase drawings! I recommend working carefully through this one, step-by-step, to help yourself understand how the phase drawings work. Right-click on it and open it in a new tab, and try this sequence of steps (the link is below the sequence):

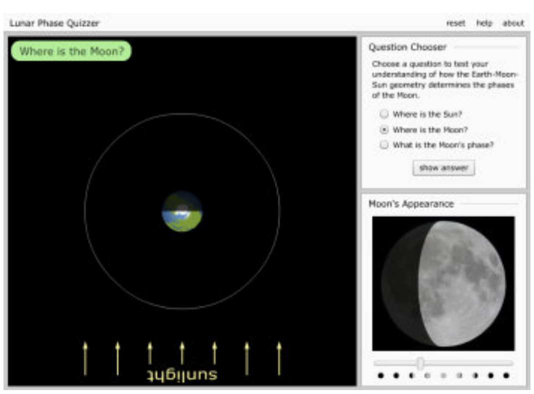
1. First, familiarize yourself with how to rotate the model. You can drag-rotate it in the usual way if you want. (Hold down the left mouse button and drag the

mouse around in the model, to rotate it.) You can also use the "left/right" andy "up/down" sliders.

2. Next, click your way through Steps 1 through 3, but, make sure you **drag-rotate the model around for a while in between each step**. That's important!
3. After you've clicked Step 5, rotate the model so you're looking "down" on the north poles of the Earth and Moon. Ask yourself what phase the Moon will show, as seen from the Earth. Then, **before you click step 6**, rotate the model so you can see the moon through the Earth. (They've made the Earth `go transparent' for this, which is handy.) Did you get the phase right?
4. Now click Step 6, to double-check your guess.
5. Having quizzed yourself once, move the "Sun Direction" and/or "Moon Position" slider, rotate the model around for a while, and try to figure out the phase.
6. Keep doing this over and over again. You could spend hours playing with this model, and if you did, it might help the idea of the lunar phases `seep into your bones' the way it does for an astronomer!



Finally, if you want to make sure you're a total bad mo-getter when it comes to Moon phases, use this simulation to quiz yourself on all aspects of the subject! You can develop Jedi-level Moon-phase skills with this!



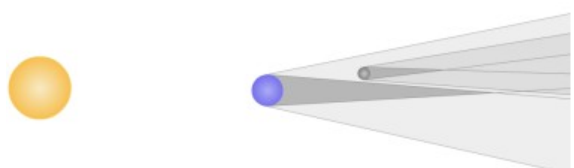
What's the difference between the Moon's **sidereal period** and its synodic period? Why is there a difference? We may or may not have gone over this in class, but it's shown on p. 35, in item 3.

Make sure you understand the difference between a **solar eclipse** and a lunar eclipse. What's the difference between a **partial** eclipse and a **total** eclipse, in both the solar and lunar cases? What's an **annular** solar eclipse? If you want to see a total or annular solar eclipse, why is it important to be in the path of totality?

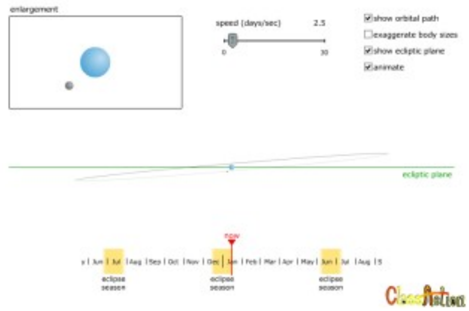
Why don't we get a solar eclipse every month? (Carefully studying Figures 3-13 and 3-14 will be worthwhile here. (They are Figs. 3-14 and 3-15 in the 9th edition.) This involves the concept of the *plane of an orbit*, which is kind of a tricky thing to visualize.

What is the **line of nodes**, and what is its importance for eclipses?

Happily, there are… you guessed it! Some nice UNL simulations to help you understand why there isn't a solar or lunar eclipse every month. Start with this next simulation, just to familiarize yourself with the idea of the umbra and penumbra some more. Move the Earth and Moon around, and compare what you see with Figures 3-2, 3-3, 3-8, and 3-9. (In the 9th edition, these are Figs. 3-3, 3-4, 3-9, and 3-10. Fig. 3-2 in the 9th edition is like one of the animations, below.)



Okay, now move on to the next simulation, which shows the Earth **as seen from the Sun**. You can watch the Moon's orbit, as the months go by, and see why the Moon doesn't always line up perfectly with the Earth and Sun. This one is a little advanced, but it's worth running the animation and comparing it to Fig. 3-13 and Fig. 3-14 (Figs. 3-14 and 3-15 in the 9th edition).



Chapter 4: The Origin of Modern Astronomy

What is **archaeoastronomy**?

What do **Stonehenge**, **Newgrange**, and the **Sun Dagger** all have in common?

Why did Plato argue that all of the motions we see in the sky can be explained by **uniform circular motion**? How was this related to the concept of the *perfection of the heavens*? (This is discussed on p. 55 (p. 56 in the 9th ed.).)

What did Aristotle say was the main difference between the Earth and the heavens? (This is related to the previous question.) What was at the center of the universe, as he saw it?

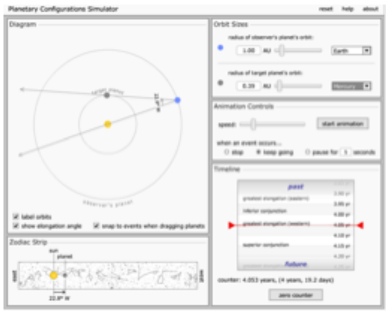
What did Eratosthenes measure, and how accurate was his measurement? Being able to draw a diagram showing how he made this measurement would be a great idea. (Studying Figure 4-7 will be helpful here. It's the same figure number in both the 8th and 9th editions.)

As seen by the unaided eye, what's special about the planets? Which ones are visible with the unaided eye? Where do we find them in the sky? (Hint: What do we call the `pathway in the sky' that the Sun, Moon, and planets all seem to travel along?)

Which two planets are only ever seen near the Sun? To understand this a little better, try the UNL "Configuration Simulator", below. Here are some tips for understanding the two `inferior planets':

1. Open the animation in a new tab or window, as usual.
2. Set the "observer's planet" to Earth.
3. Set the "target planet" to Mercury.
4. Run the animation.
5. Experiment with checking and un-checking "show elongation angle".
6. After you've played with this for a while, try it all over again with Venus as the

"target planet".

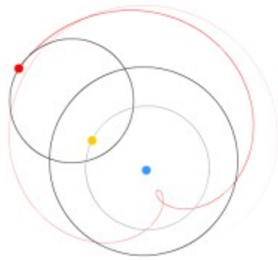


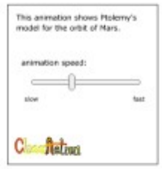
What is **retrograde motion**? (Hint: It's a good idea to be really clear on retrograde motion---both what it appears to be, and what it really is. The rest of this chapter will make a real big deal about it.)

How did Ptolemy explain things like the retrograde motion of Mars? What's an **epicycle** and a **deferent**? Carefully studying the two-page spread about `The Ancient Universe' on p. 58-59 will be very useful. (p. 60-61 in the 9th edition)

If you're feeling adventurous, you can play with the next UNL simulation, although it's kind of advanced. It simulates the Ptolemaic universe, and is worth comparing to "The Ancient Universe" on p. 58-59 (p. 60-61 in the 9th edition). It's rather complicated, though, so if you try it, plan on spending some time figuring out what all the controls do. If you've got the time, though, you can become like Ptolemy himself!

Even if you didn't have time to investigate that last simulation very deeply, try playing around with this next model, which shows Mars in the Ptolemaic system. (Big thanks to the folks at UNL!) Earth is the yellow dot, Mars is the red dot. When, in this model, does Mars show a retrograde motion, as seen from the Earth?



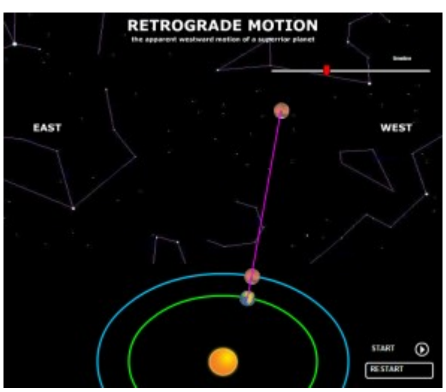


What was fundamentally different between Copernicus' model of the universe and the models of Ptolemy and Aristotle? (Hint: Carefully compare `The Ancient Universe' with Copernicus's model in Fig. 4-10. The figure number is the same in both editions.)

Why didn't the pre-Copernican astronomers believe in the sort of model that Copernicus argued for? In other words, what was their argument against it? (Hint: How is it related to the thumb on p. 58? (p. 60 in the 9th ed.)) Is there a way for the Copernican model to be correct, even if the `thumb effect' is not seen? What would this imply about the *outermost* part of the model?

Here's a huge point... a really important one to understand... How did Copernicus' model of the solar system explain *retrograde motion* in a simpler way than the earlier models?

In fact, you may find it helpful to play with the model show below (As always, it's from UNL.) I recommend dragging the red slider along the timeline, so you can control the planets for yourself.



Copernicus's model wasn't perfect - what were some of its flaws? Did it predict the positions of the planets any better than its competitor at the time? (Hint: The textbook's section on `*De Revolutionibus*' is worth reviewing in detail here, especially the part about the *Prutenic Tables* versus the *Alphonsine Tables*, which we may not have talked about in detail in class.) Which was more accurate in the long run: The Copernican **model**, or the Copernican **hypothesis**? What was a basic part of Copernicus's model that was later modified by Kepler?

Make sure you understand the importance of Galileo's work. Here are some things to be clear about:

<u>Galileo and the telescope:</u>
Did he really invent the telescope?

<u>Galileo and the Moon:</u>
When he looked at the Moon through the telescope, what did he see that challenged the then-accepted Aristotelian ideas about the Moon?

<u>Galileo and the Milky Way:</u>
When he looked at the Milky Way through the telescope, what unexpected thing did he see?

<u>Galileo and Jupiter:</u>

- When he looked at Jupiter through the telescope, what did he see?
- What was really weird about what he saw around Jupiter? Why would people find it hard to accept?
- How did his observations of Jupiter provide some support for the Copernican model?

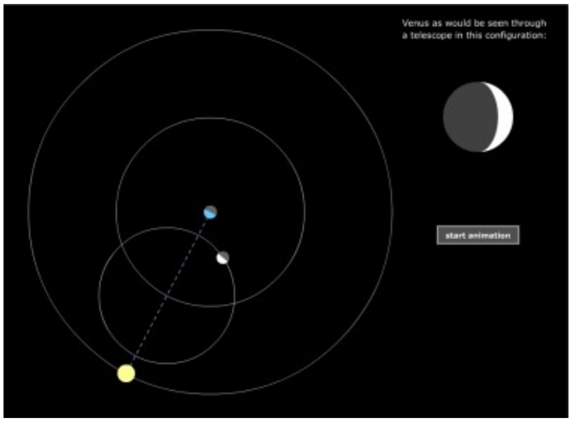
<u>Galileo and Venus:</u>

- When he looked at Venus through the telescope, what did he see?
- What did the Ptolemaic model of the solar system predict about the appearance of Venus? (Hint: See Fig. 4-18. (Fig. 4-17 in the 9th edition))
- Did Galileo's observations of Venus fit these expectations?
- Did they fit the Copernican model better or worse than the Ptolemaic one?

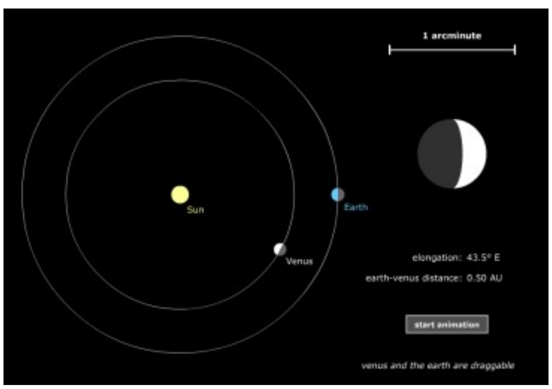
(Hint: As with Copernicus and retrograde motion, it wouldn't be a bad idea to be able to explain the `Galileo Jupiter story' and the `Galileo Venus story' to a fellow student, such as by making some well-labeled drawings like the ones in your notes.)

Try the simulations shown below, to better understand the `Galileo Venus story'. (As always, many thanks to the good folks at <u>UNL</u>!)

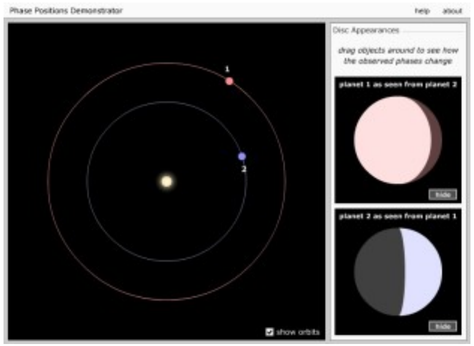
1) Play with this model, which shows VENUS'S PHASES IN THE PTOLEMAIC SYSTEM. (I recommend right-clicking it and opening it in a new tab.) Run the animation a few times, stop it, start it, and ask yourself this question: What is the only phase that Venus shows in this model? Compare the animation to Fig. 4-18. (Fig. 4-17 in the 9th edition)



2) Now, play with this next model, which shows VENUS'S PHASES IN THE COPERNICAN SYSTEM. (Again, I recommend right-clicking it to open it in a new tab.) Drag Venus and the Earth to different positions, and see what Venus looks like from the Earth. Run it as an animation a few times. Always try to make sure you can understand why Venus shows the phase it does, as seen from the Earth. What phase does Venus show, in this model, that it didn't show in the Ptolemaic model? (Looking at Fig. 4-18 would be a good idea here, too.) (Fig. 4-17 in the 9th edition)



And if you're just *dying* to do *one more* simulation, try this one… which planet is Earth, and which one is Venus?



Now we deal with Tycho Brahe, another really important figure in the history of astronomy:

How did Tycho's model of the solar system represent a compromise between the geocentric and heliocentric models? (See Fig. 4-11 on p. 64 (p. 65 in the 9th edition)).

When compared with Aristotle's ideas, what was really weird about the `new star' in 1572? How did he show that it wasn't below the `sphere of the Moon'? (This is explained in Figure 4-12, but the explanation itself is hard to figure out. It's worth spending some time looking at Fig. 4-12 and re-reading the paragraph that begins "In 1572, a "new star"…".)

What important information did Tycho collect, which became important for Kepler?

Next, we dealt with Kepler, who figured out some very important things about the planets' orbits:

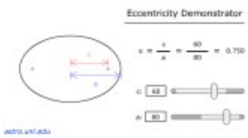
Kepler's First Law - Make sure you understand the following points, which are covered on p. 67 (p. 68 in the 9th ed.):

- What is an *ellipse*?
- What are the *foci* of an ellipse?
- What's the *semimajor axis* of an ellipse?
- What does it mean if an ellipse has a high *eccentricity*?
- What do ellipses have to do with planetary motion?
- Make sure you don't confuse the terms *ellipse* and *eclipse*.

To better understand what an ellipse is, and what eccentricity is, play around with the next UNL simulation. Try this:

1. Move the sliders around to make the orbit look more eccentric or less eccentric.
2. If the number "e" has a large value, is the orbit more elliptical-looking, or less elliptical-looking?

3. Where are the foci in this simulation? (Make sure to compare the simulation to Fig. 4-14.)



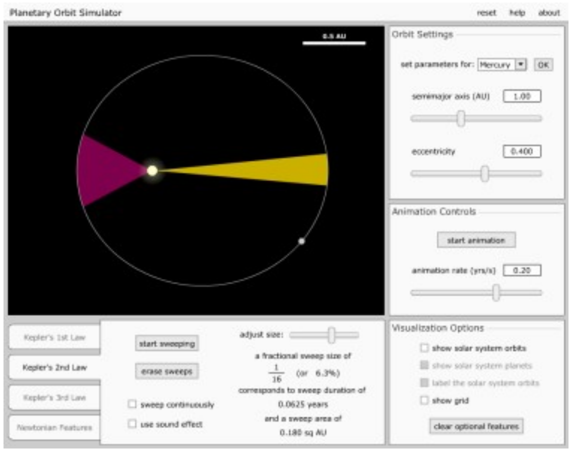
Kepler's Second Law - Make sure you understand the following points:

- What does the Second Law say?
- What is *angular momentum*? What's the analogy to an ice skater?
- Where, in its orbit, would an object be moving the *fastest*? Moving the *slowest*?

Kepler's Third Law - Make sure you understand the following points:

- As you go *farther* from the Sun, what happens to the *time* that it takes a planet to orbit the Sun?
- What does this imply about the *speed* at which, say, an outer planet is moving (relative to an inner one?)
- Would a `year' on an inner planet (like Mercury) be *longer* or *shorter* than the Earth's year? How about for an outer planet (like Neptune)?

As always, there's a detailed UNL simulation for Kepler's Laws. Like some of the other simulations, this one is very detailed. You might find yourself getting lost in all the details. But, if you have time to play around with it, exploring it step-by-step, you can learn a lot about Kepler's laws of planetary motion. This would be a great simulation for you to explore in a group study session, or for one or more students to explore with me during office hours!



Chapter 5: Gravity

Newton discovered three laws of motion that provided the foundation for understanding things like the orbits of planets around the Sun. There are a fair number of terms and details to keep straight when studying Newton. Here are some things to make sure you understand:

What is **Newton's First Law**? (Note: It's basically the same thing as Galileo's `law of inertia', which is described on p. 80.) (It's p. 82 in the 9th edition, and they put the term **inertia** in boldface in the 9th edition.) If an object is moving through space at a constant speed, in a straight line, what will happen to it, if no forces act on it? The textbook described Newton's laws of motion fairly briefly, but we may have made drawings in class showing a spacecraft that has its motion changed by forces. If you have these drawings in your notes, it's well worth reviewing them in detail. Make sure you're clear on how **forces** are what cause **changes in motion**.

What's a specific term we used for a `change in motion'? In class, we may have talked about how, in your car, you've got *three* controls for changing motion, rather than just the *one* that most people think of . In our drawings of the spacecraft, how did we show three different sorts of changes in motion?

What is **Newton's Second Law**? You can learn it using the equation on p. 81 (p. 83 in the 9th ed.) if you want, but it may be easier to think of it this way:

If we apply a *larger* force to an object, do we get a bigger change in motion, or a smaller one?
If we make an object *more massive*, will the same force cause a bigger change in motion, or a smaller change?

(Hint: Think about hitting a baseball with a bat. This causes the ball's motion to change. Think about how a *harder* hit, or a *heavier* ball, would lead to different scenarios for the ball's change in motion.)

What is Newton's **Third Law**? This is the one that people have most commonly heard expressed as a spoken or written phrase. Here's an example of something important to understand about the Third Law: How does it allow a rocket to work? Is it really necessary for the rocket's exhaust to *hit* something, in order for the rocket to move? Or can a rocket, floating in empty space, ignite its engine and start moving? How is the Third Law relevant here?

Astronomy 4

Section 1 (M through F, 8:30-9:20 am)

Here are the chapters to know for Test 2, in the order that we covered them:

Chapter 5 (the part about gravity, orbits, and tides)
Chapter 6 (Light and telescopes)
Chapter 7 (Atoms and the electromagnetic spectrum)
Chapter 19 (Origin of the solar system)
Chapter 8 (The Sun)
Chapter 20 (Earth: The Standard of Comparative Planetology)
Chapter 21 (The Moon and Mercury: Comparing Airless Worlds)

Chapter 5: Gravity

(After Test 1, we finished Chapter 5 by talking about Newton's work on gravity, orbits, and tides.)

Newton also came up with a very important idea called **mutual gravitation**. What does this mean? For example, if you travel across the universe, are you ever `beyond' the gravitational pull of the Earth?

What does it mean to say that the law of mutual gravitation is an *inverse square law*? Both light and gravity follow inverse square laws - it will be worth studying Fig. 5-6 on p. 83 here. (It's Fig. 5-5 on p. 85 in the 9th edition.)

(If you're feeling ambitious, you might want to play with UNL's Gravity Algebra simulation and their Newton's Law of Gravity Calculator . I've included these as text links, so people won't get too scared if they see something math-y-looking. However, even if you don't like math, these simulations might be worth exploring, because they do the math for you! They show what the results of Newton's `gravity math' are, when you stick different numbers into the formulas.)

Make sure you understand Newton's explanation of how orbits and orbital motion work. Figure 3 in the two-page spread on `Orbiting Earth' (`Orbits' in the 9th ed.) will be particularly important to understand here. You don't need to know the equation for orbital velocity, but make sure you understand why there is a certain orbital velocity for any given planet. In class, we probably talked about orbits by using the example of a cannon shooting cannonballs from the top of a tall tower. The textbook shows this in the `Orbiting Earth' spread, using the example of a tall mountain instead of a tall tower.

Another really useful way of understanding an orbit is the illustration in Fig. 1b of `Orbiting Earth'. In this example, the Moon's near-circular orbit it divided into many small segments. In each segment, notice how the Earth's gravity keeps *changing the direction* of the Moon's motion. Make sure you recall and understand that these changes of direction are examples of *acceleration*, and that this acceleration is caused by a *force*.

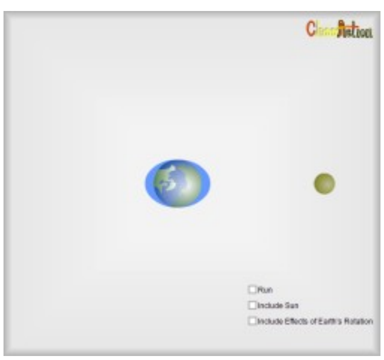
Here's an important point to be clear about: If you see an image of an astronaut floating `weightlessly' inside a spacecraft, what is *really* causing this? Have they really gone beyond the gravity of the Earth, as most people imagine?

EXTRA CREDIT: Memorize the equation for orbital velocity and be able to calculate the orbital velocity for a planet if you're given its mass, radius, and the value of G, the gravitational constant.

EXTRA CREDIT: Memorize `Newton's form of Kepler's Third Law', and use it to calculate the mass of a planet, if you're given the size of one of its moon's orbits, and the period of that moon's orbit.

How do the *tides* work? (Our textbook is one of the few that gives a correct presentation of how the tides work, as shown in Fig. 5-8). (It's Fig. 5-7 in the 9th edition.) How did tidal forces cause the Moon to `lock' its rotation so that it always has the same side facing the Earth? (The textbook may not fully explain this; we may have gone over it in class.)

You can get an idea of what the tidal bulges look like by running this UNL animation:



It's worth comparing that simulation in some detail to Fig. 5-8 on p. 90. (It's Fig. 5-7 in the 9th edition, on p. 92.) Here are some things to examine:

- Note that the simulation shows the bulging of the Earth's *oceans*. The solid body of the Earth and Moon bulge, too, but it's too small to notice at this scale.
- The most basic, starting configuration of the animation shows the basic tidal bulges, as shown in the first panel of the figure.
- To better understand the second panel of the figure, check the "Include Sun" box.
- To simulate the third panel of the figure, check the "Include Effects of Earth's Rotation" box.

Chapter 6: Light and Telescopes

What is *electromagnetic radiation*, and how is it different from the radiation that would come from a radioactive substance? (The textbook discusses a `Common Misconception' about the term `radiation' on p. 101 (p. 104 in the 9th ed.).)

It's important to remember that light can be thought of as both *waves* and *particles*. (This is discussed on p. 101 and 102. (p. 104 and 105 in the 9th ed.)) When we think of light as a wave, what are the two *fields* that are vibrating as the waves move through space?

(Note: There's a slightly misleading sentence on p. 102 that might confuse you here. (This is on p. 105 in the 9th edition.) It says "In contrast, light is made up of electric and magnetic fields that can travel through empty space." It isn't actually the fields that are moving. The electric and magnetic fields permeate all of space. It's disturbances in those fields, which we call `waves' [by analogy to disturbances of the ocean's surface], that are moving through space.)

What do we mean by the *wavelength*, *amplitude*, and *frequency* of an electromagnetic wave? What is the *speed* of all electromagnetic waves?

What is the electromagnetic spectrum? To what portion of it are our eyes sensitive? What portions of the electromagnetic spectrum come through our atmosphere?

Study Fig. 6-3, and make sure you know the major parts of the electromagnetic spectrum, and how they are arranged relative to each other (in terms of their wavelength):

- Gamma rays
- X-rays
- Ultraviolet
- Visible
- Infrared

- Radio

Now for some things to know about *telescopes*:

First, recall the three things a telescope does:

- Magnify
- Gather light
- Resolve small details

What are the two basic types of telescope? (Figures 6-5a and 6-6 will be particularly useful here) How does each type of telescope gather light?

That list of three things a telescope does - which of those things is/are influenced by the telescope's *aperture*, and which is/are influenced by the telescope's *focal length*? (Figs. 6-5b and 6-9 will be worth studying here, as will the textbook's description of `The Powers and Limitations of Telescopes' on p. 106-108. (p. 109-112 in the 9th edition))

What do we call the problem that a refracting telescope has with color? Make sure you understand Fig. 6-7. Does a reflecting telescope have this same problem?

What is a telescope's *mounting*? Why would you want to use a very steady, high-precision mounting for your telescope? Why would the apparent diurnal motion of the sky be a problem for an astronomer, and how does the telescope's mounting counteract this effect? (Fig. 2 in `Modern Optical Telescopes' will be useful here.)

What is *seeing*? Why would it help an astronomer to build a telescope on top of a high mountain or to put a telescope in space? What are *adaptive optics*, and how do they help? What is light pollution, and how do astronomers cope with it?

Are all telescopes designed to operate at visible-light wavelengths? Which of the two main types of telescope would a *radio telescope* be an example of?

What are the advantages of placing a telescope in space?

Make sure you remember the three basic things that astronomers do with the electromagnetic radiation that their telescopes gather:

- Imaging
- Spectroscopy
- Photometry

What's a charge-coupled device (or `CCD')? What advantages do CCDs have over the old photographic plates? Is it possible you're carrying one or more CCDs with you on a daily basis, and if so, where?

Chapter 7: Atoms and Starlight

What are the three kinds of *particles* in an atom? Which ones make up the *nucleus*? Which ones `orbit' the nucleus? (We probably mentioned in class that `orbit' isn't really quite the right description, and it's also mentioned in `A Model Atom' on p. 127. [p. 131 in the 9th edition])

What are the *permitted orbits* of an electron?

How does the absorption of light relate to electrons and their permitted orbits? How is this related to the idea of *energy levels* and an *excited atom*? You should carefully study `The Excitation of Atoms' and `Radiation from a Heated Object' on p. 130 and 131 (p. 134 and 135 in the 9th edition). Here are some specific things to understand from these pages, and from our discussion of them in class:

- When an atom absorbs a *photon*, what happens to an orbiting electron? (Figs. 7-4 and 7-5 will be useful here.)
- Can an atom absorb a photon of any old wavelength?
- Can an atom emit energy that it's absorbed?
- If so, how does this affect an electron's energy level, and what gets emitted?

The next part of Chapter 7 to learn is the two-page spread on `Atomic Spectra', on pages 136 and 137 (p. 140 and 141 in the 9th edition). Make sure you understand the differences between these three types of spectra, and how each one forms:

- Continuous
- Absorption
- Emission

Which type of spectrum would a hot, glowing object (like a light bulb or star) produce? (This is related to *thermal energy* and *blackbody radiation*, which are discussed on p. 131. [p. 135 in the 9th edition]) If we observed a planet with a spectrograph, would we be likely to see the same type of spectrum? Why or why not?

How does the observation of a planet's spectrum allow us to figure out what kinds of atoms and compounds it's made of?

What is the *Doppler effect*? How do we use *redshifts* and *blueshifts* to measure the velocity of an object? (We'll come back to this concept again at the end of the quarter, when we talk about techniques for detecting planets around other stars.)

Chapter 19: The Origin of the Solar System

At this point, we jumped ahead to Ch. 19 (Ch. 10 in the 9th edition), to talk about the basic structure of the solar system, and how it formed. (After this, we went back to the normal order of things with Chapter 8.)

First, make sure you understand the overall structure of our solar system. Here are some specific things to make sure you know and understand:

- What's at the center of our solar system?
- What do we mean by the *plane* of the solar system, and how is this related to the idea that "the solar system is basically flat and disk-shaped" ? (See p. 408 [p. 196 in the 9th edition].)
- How are the *revolutions* of the various bodies in the solar system related to the original *rotation* of the disk? (Again, see p. 408 [p. 196 in the 9th edition].)
- Where, in the solar system, do we find debris left over from the solar system's formation?
- What are the two `belts', and where is each one located?
- What are the objects in each belt mostly made of?
- What are the <u>two major kinds</u> of planets in our solar system, and what are the planets in these two categories made of?

What is the *age* of the solar system? How does *radioactive decay* allows us to determine the age of a rock or a meteorite?

The story of how the solar system formed is the story of the *solar nebula*. There are a number of aspects of the nebular theory that you should know and understand (and be able to explain on the test):

What two elements was the nebula mostly made of? Where, in today's solar system, do we find objects mostly made of these elements? Are the Earth (and the other planets in its `category') made mostly of these elements?

Here's a really important concept to understand: The ***condensation sequence***. The textbook's description is on p. 414-415 (p. 206-207 in the 9th edition). Was the composition of the original solar nebula very different from place to place? If not, how could planets of such different compositions form? This is where you should make sure you understand the condensation sequence. How did *temperature* vary from the *inner* solar system to the *outer* solar system? How did this affect the types of materials that could *condense* into small grains?

(Here's a really handy tip: Make sure to read about the `**Common Misconception**' described on p. 415! (It's p. 207 in the 9th edition.) We probably emphasized this point in class. This is something that trips up a LOT of students! When you encounter questions about the formation of the solar system on a test, make very sure you don't fall into this trap!)

Okay, now that you have a good understanding of how tiny, dust-sized grains condensed from the solar nebula, it's time to think about the next step: The *accretion* of *planetesimals*. The textbook describes this on p. 415-416 (207-208 in the 9th edition), and it's worth re-reading that description carefully, along with any class notes on this topic. There are some analogies to snowflakes that may be helpful here.

In this story of the formation of the solar system, there are three terms that get used a lot: *Particles* of metal, silicates, and/or ice, *planetesimals*, and *protoplanets*. Make sure you can keep them straight; a handy thing to do is to make sure you understand the approximate size divisions between each of these categories. (These may be in your class notes, and they're in the textbook if you look closely.)

As planetesimals grew larger, processes like *gravitational collapse*, *differentiation*, and *outgassing* could happen. Make sure you understand (and can explain) what each of these processes is, and how each one works.

What's the *Jovian problem*, and how does the idea of *direct collapse* offer a potential solution?

Finally, how did the solar nebula get cleared out? (This is nicely described on p. 420-421, or p. 212 in the 9th edition.) There are two main parts to this: 1) The clearing out of gas and very small, leftover dust particles - how did this happen? 2) The `sweeping up' of planetesimals and other small debris by the planets. What `scars' do the solid planets (and the moons of the outer planets) still show, from this `sweeping up' process?

Chapter 8: The Sun

The Sun's diameter is about how many times bigger than the Earth's?

What are the two most abundant chemical elements in the Sun? The remaining elements make up about what total percentage of the Sun's mass? (You will find it helpful to look at `Composition of the Sun', on p. 148-149 [p. 154 in the 9th edition], particularly the part about Cecilia Payne's discoveries.)

Make sure you're clear on the basic parts of the Sun, particularly the *core*, *radiative zone*, *convective zone*, *photosphere*, *chromosphere*, and *corona*.

Which part of the Sun does the sunlight that we see come from? If you wanted to see the corona from the surface of the Earth, what sort of event will you have to wait for?

What causes the *granulation* that we see in the photosphere? (Figure 8-2 will be useful here, and this is related to the difference between the radiative and convective zones, see Fig. 8-15 for those. [Fig. 8-16 in the 9th edition])

What is *nuclear fusion*? What's the difference between fusion and *fission*? I may have told a goofy `analogy story' in class, describing two protons that get slammed into each other and fuse together. Why did they (initially) find each other `repulsive'? What force took over and made them say `ooh, I find you so powerfully attractive!' when they were slammed sufficiently **close** together? (Studying Section 8-3, `Nuclear Fusion in the Sun', will be helpful here.)

EXTRA CREDIT: Memorize the `proton-proton chain' shown in Figure 8-14 on p. 162 (Fig. 8-15 on p. 168 in the 9th edition), and be able to answer questions about it. Here are examples of good things to know:

- *How many protons go **in** to reactions in the proton-proton chain?*
- *Do any protons come **out** of reactions in the proton-proton chain?*
- *In what forms does energy emerge from the proton-proton chain?*
- *How does nuclear fusion heat the gas that makes up the Sun's core?*
- *What types of particles and/or electromagnetic radiation are produced in the proton-proton chain?*
- *What is the equation that describes the conversion of mass into energy?*

Chapter 20: Earth: The Standard of Comparative Planetology

Which planetary bodies are the *terrestrial* ones? (Hint: Figure 20-1 will be useful here. It's Figure 11-1 in the 9th edition.)

What are the major *compositional* layers of the Earth? Which layer(s) is/are solid, and which layer(s) is/are liquid? (Celestial Profile 2: Earth will be useful here, as will Section 20-3 on `The Solid Earth'. [It's Sec. 11-3 in the 9th edition.])

How do seismic waves act as `probes' of the Earth's interior structure? (Again, this is mostly in Section 20-3. [11-3 in the 9th edition])

What is the Earth's *magnetic field*, and how does it form? What does it generally prevent from reaching most of the Earth's surface? In class, we probably talked about the three basic ingredients needed in order for a star or planet to have a magnetic field. What were they? How does the Earth have each of these things?

What are the `*Four Stages of Planetary Development*' described in Chapter 20? (= Chapter 11 in the 9th edition) (Note that these are different from the `condensation sequence' that you learned about in chapter 19 [Ch. 10 in the 9th ed.].)

Why do so many planetary bodies show evidence of *impacts*? What is this evidence? Why does this evidence often get erased on the Earth, more so than on many other planetary bodies?

What is *plate tectonics*, and what is the role of the *lithosphere* in this process? What's the difference between a *midocean ridge* (called a `midocean rise' in the textbook's 2-page spread on `The Active Earth'), and a *subduction zone*?

What are the two most common *gases* in the Earth's *atmosphere*? What are the next two most abundant? What do planetary scientists think the Earth's early atmosphere was made of, and how did it acquire this atmosphere? (Note: You'll want to carefully study `Origin of the Atmosphere', which starts on p. 440 (p. 233 in the 9th ed.), and make sure you're clear on the **new** ideas about the origin of the Earth's atmosphere. Note that these are different from the **old** idea of a `primary' atmosphere followed by a `secondary' atmosphere.)

How did the Earth get the *oxygen* in its atmosphere?

What is the *ozone layer*, and how is it important for life?

Extra Credit: Be able to explain how plate tectonics works as a recycling system, and how this could `erase' evidence of impacts.

Chapter 21: (The Moon and Mercury: Comparing Airless Worlds)

If you're looking at the Moon, what is the *terminator*? (You may remember this from our discussion of the phases of the Moon, back in chapter 3.)

If a friend claims they've looked at the Moon's *farside* through a telescope, why would this be unlikely? How is the idea of *tidal coupling* related to this question?

What is the diameter of the Moon relative to the Earth? What material does the Moon NOT contain much of, based on its density?

What are the differences between the *maria* and the *highlands*? Make sure you understand how you could tell them apart if you were looking at the Moon through a telescope or from an orbiting spacecraft: In other words, what <u>looks</u> different about them? What are the differences between them in terms of composition and age? What type of rock is each one made of?

What is the difference between *relative* age-dating and *absolute* age-dating? How can craters be used to date the relative ages of different parts of a planetary surface? (And how is this applied in the case of the lunar highlands and the maria?)

Make sure you understand how *impact craters* form, and why they're (essentially) always circular, even if the `projectile' comes in at a shallow angle.

What's the relationship between the highlands and the Moon's primordial *magma ocean*? How does this relate to the *giant impact theory* for the formation of the Moon? (Make sure you have a good understanding of the giant-impact theory, and the major evidence for it. The section on `The Origin of Earth's Moon', on p. 460, goes over this in detail. It's p. 255 in the 9th edition.)

When samples of the Moon were returned by the Apollo missions, what were the absolute ages of the highlands and the maria? Did this argue **for** or **against** the relative ages of the highlands and maria, based on crater ages?

What's an *impact basin*, and what's the relation between maria and basins? (The section on `A History of the Moon', starting on p. 458 [p. 252 in the 9th edition], and particularly the part about Mare Imbium, will be useful here.)

What's *anorthosite*? What's *basalt*? What's *breccia*? How does each one form?

Then, it was on to Mercury, the innermost planet...

The early telescopic observations of Mercury suggested that its rotation was tidally locked to the Sun. How did radio astronomers (in 1962 and 1965) determine that it isn't tidally locked? What are the rotation period and the orbital period of Mercury, expressed in Earth days?

Make sure you understand the *resonance* between Mercury's rotation and revolution periods. What does this mean for the `length of a day' on Mercury? How many Mercury years would elapse between two successive noons on Mercury? We probably made a sequential drawing in class, depicting the spin-orbit resonance of Mercury - this would be a good thing to be able to redraw, when you're studying for the test. (As you practice this, it will be worth comparing your notes and your practice drawings to Figure 21-12. [It's Fig. 12-11 in the 9th edition.])

What are the temperatures on the sun-facing (day) side and the night side of Mercury?

Does Mercury have much of an atmosphere? Where does its `atmosphere' come from?

What are the *lobate scarps* on Mercury, and what do they imply for changes in the <u>size</u> of the planet (or at least its outermost layers)?

What is the *Caloris Basin*, and why does the part of Mercury 180 degrees away from it look weird? (Figure 21-15 will be useful here. [It's Fig. 12-14 in the 9th ed.])

What makes the *intercrater plains* and *smooth plains* of Mercury smooth? (Note that the MESSENGER spacecraft has recently confirmed this with high-resolution imagery.) How is this similar to the story of the lunar maria?

What does Mercury's high *density* tell us about its interior? What part of Mercury's interior is significantly larger than its counterpart in either the Earth or the Moon?

Astronomy 4

Section 1 (M through F, 8:30–9:20 am)

Here are the chapters to know for Test 3, in the order that we covered them:

Chapter 22 (Venus and Mars) [It's Chapter 13 in the 9th edition.]

Chapter 23 (Jupiter and Saturn) [It's Chapter 14 in the 9th edition.]

Chapter 24 (Uranus and Neptune) [It's Chapter 15 in the 9th edition.]

Chapter 25 (Meteorites, Asteroids, and Comets) [It's Chapter 16 in the 9th edition.]

Chapter 22: Venus and Mars

(This is Chapter 13 in the 9th edition.)

How does Venus compare to the Earth in terms of size, mass, and distance from the Sun?

What is the rotation period of Venus? What does it mean that Venus's rotation is *retrograde*?

What is Venus's atmosphere made of? What are its clouds made of? What are the temperature and pressure at its surface? Would this be a good environment for Earth-like life, and why or why not?

What is the *greenhouse effect*, and how does it work? (We probably made a sketch showing how this works, in class. Make sure you're clear on the roles that **visible light**, the **planet's surface**, **infrared radiation**, and **greenhouse gases** play. Note that there is a good explanation of the greenhouse effect back in the chapter on the Earth, starting on p. 444. [= p. 237 in the 9th ed.])

Why doesn't the Earth have as strong of a greenhouse effect as Venus? Where (and in what form) is most of the Earth's CO_2? (Note: The section on `The Venusian Greenhouse' in Chapter 22 [= Ch. 13 in the 9th ed.] will be worth reading in detail here.)

Why can't we see the surface of Venus from the Earth? How do spacecraft `see' the surface?

Why do they often make pictures of Venus' surface look orange, such as in Fig. 22-3? (It's Fig. 13-3 in the 9th ed.) What colors does the surface really show? (Compare Figs. 22-2 and 22-3 [Figs. 13-2 and 13-3 in the 9th ed.], and make sure to study the discussion of the surface color on p. 474. [269-270 in the 9th ed.])

What's the most common type of volcano on Venus? Where would we find examples of this type of volcano on the Earth and Mars? (The two-page spread on `Volcanoes' will be useful here.)

Does Venus have Earth-style plate tectonics? What features of Venus's surface are similar to the Earth's major tectonic features?

What did the distribution of craters on Venus's surface tell us about the `resurfacing' of the surface? When did this happen, and what kind of material `resurfaced' the planet?

Next, Mars...

How do the size and mass of Mars compare to the size and mass of the Earth? What implications do size and mass have for the history of a planet, and for Mars' likely amount of geologic activity today, as compared to the Earth?

What are the similarities between Mars' seasons and the Earth's seasons, and between Mars's day length and the Earth's day length?

In class, we talked about the concept of an *opposition* of Mars, and we may have demonstrated this using the planetarium's digital projection system. What is an opposition, and why is it the best time for observers using ground-based telescopes to study Mars?

When the first telescopic observations were made of Mars, how did a mis-translation of the Italian word *canale* lead to fanciful ideas about intelligent life on Mars?

What is the atmosphere of Mars mostly made of? How do the atmospheric pressure and temperature at Mars's surface compare to those of the Earth?

How do the atmospheric conditions at Mars's surface affect the possibility of liquid water existing there?

What other factors make it tricky for life to exist at Mars's surface? (We may have made a list of these in class.)

What gives Mars its reddish color? How is this related to the abundance (or lack) of oxygen in the atmosphere?

- What are the basic characteristics of Mars's atmosphere? Here are some specific things to know:
- What is Mars's atmosphere mostly made of?
- What is the atmospheric pressure like at Mars's surface?
- Besides the fact that Mars is farther from the Sun than the Earth, why is the temperature at Mars's surface colder than on Earth?
- Where is most of the oxygen that might otherwise be in the atmosphere?
- What are some of the reasons why Mars's atmosphere is so thin? (It will be worth carefully studying the text on p. 486 and in the first column on p. 487.) [In the 9th edition, these are the last paragraph on p. 279 and the first column on p. 281.]

In addition to being familiar with the Martian atmosphere, what does this mean for water on the surface? What form can water NOT exist in on the Martian surface (at the present time)?

In addition to the water story from the last question, what are the characteristics of the Martian surface and atmosphere that make it a tough place for life?

Next we talked about the geology of Mars in some detail. Here are some things you'll want to know about this:

What's the big difference between the southern half of Mars and the northern half? (How do they look different? What does this tell us about their ages and histories?) Figure 22-15 [= 13-14 in the 9th ed.] will be helpful here, as will the similar figure in the upper-left corner of p. 497 [= p. 291 in the 9th ed.].

What's the *Tharsis bulge*? What are the three big, spectacular things on it? How are these things different from their Earthly counterparts? What does this suggest about plate motion (or the lack of it) on Mars? (There's a helpful section that starts at the end of p. 487, and goes to the first part of p. 490. [In the 9th edition, it starts with the second column of p. 282, and goes to the first part of p. 284.] In the last part of this discussion, they refer back to p. 478-479, about `Volcanoes' - there are some useful illustrations there. [The equivalent `Volcanoes' section in the 9th edition is on p. 272-273.)

What's the *Valles Marineris*? How does it compare to something like the Grand Canyon? The Grand Canyon was carved by flowing water---was the Valles Marineris carved the same way?

What is the evidence for water on the surface of Mars in the past? What is the difference between the *outflow channels* and the *valley networks*? What's so special about the *Eberswalde delta*? (This is the delta shown in Fig. 22-18 of the 8th edition. The 9th edition doesn't have this image, but it shows examples of water-related features of various types, such as gullies and `runoff channels'. The 9th edition does, however, describe this delta, and its significance, in the second paragraph on p. 287. Here is a link to a picture of the Eberswalde delta.)

Extra Credit: How does the deuterium-hydrogen ratio in Mars's atmosphere suggest that it once had much more water than it does now? You'll probably also find it useful to read about Venus's deuterium-hydrogen ratio, which tells a somewhat similar story. (See the section on `The Atmosphere of Venus'.) The story of Mars's argon is also similar, and this, too, is discussed in Chapter 22 [=Ch. 13 in the 9th edition]. Nick Strobel also has an explanation in his astronomy notes.

What evidence is there for ice on (and just below) the surface of Mars at the present time?

What evidence did the Mars Exploration Rovers (particularly the `Opportunity' rover) find to support the idea that some rocks on Mars were deposited in water? We saw some of this story in the `Five Years on Mars' video.

(The textbook has a nice, detailed section on `Finding the Water on Mars', starting on p. 490. [= p. 284 in the 9th edition] This will probably be helpful in sorting out the Mars water story.)

The Earth's moon has a certain size compared to the Earth. Are Mars's moons Phobos and Deimos similar, in proportion to Mars? Larger? Smaller? What's one idea for how Mars came to have these moons?

Chapter 23: Comparative Planetology of Jupiter and Saturn

(This is Chapter 14 in the 9th edition.)

Let's start with *Jupiter*. It has most of the mass in the solar system, outside of the Sun.

Once again, what's the difference between Jupiter & Saturn compared to the *terrestrial planets*? Why is it more appropriate to call Jupiter and Saturn the `liquid giants' rather than the `gas giants'? (The textbook talks about this in `Atmospheres and Interiors' on p. 503. [= p. 297 in the 9th edition])

Does Jupiter have a solid surface? If you dropped down through the atmosphere of Jupiter, what would happen to you? Would you land on a solid surface? What is the interior of Jupiter made of? How do astronomers come up with models for planetary interiors, like the ones shown for Jupiter and Saturn on p. 520? [These diagrams are on p. 313 of the 9th edition.])

Here are some things to know about Jupiter's atmosphere and weather patterns:

- What gases is the atmosphere mostly made of?
- What are the cloud layers made of?
- What is the difference between the *belts* and the *zones*?
- What's an example of a very long-lived storm in Jupiter's atmosphere?
- What are some reasons the Earth has `wave-shaped' weather patterns and Jupiter has *belt-zone circulation*?

How does the orbital velocity of a moon like Io demonstrate that Jupiter must be much more massive than the Earth? (Figure 23-2 in the textbook shows this, and it goes back to the idea of Kepler's laws. It's Fig. 14-1 in the 9th edition.)

What produces *Jupiter's magnetic field*? (And while we're at it, what are the three ingredients for a planetary or stellar magnetic field, again? Reviewing which objects in our solar system have magnetic fields will probably be helpful here, as you study for the final.) How does the *Io flux tube* relate to the magnetic field and the auroras?

What are the *Galilean satellites* (a.k.a. Galilean moons) of Jupiter? What is their order, going outward from Jupiter? (See Fig. 23-5 from the textbook. It shows them in order, going outward, from left to right. It's Fig. 14-5 in the 9th edition.)

What do planetary scientists think is the big difference between the interiors of *Ganymede* and *Callisto*? What is the evidence that Ganymede has had more geologic activity on its surface than Callisto? (Figures 23-6 and 23-7 in the textbook will be helpful here.)

Why would we expect the surfaces of the inner Galilean moons to have more craters than the surfaces of the outer moons? (Figure 23-8b will be useful here. It's Fig. 14-8b in the 9th edition.)

Do the innermost Galilean moons actually show the numbers of craters we'd expect? What does this tell us about the ages of their surface?

What has the *tidal heating* done to *Io*'s interior? How is this manifested (in spectacular fashion!) on the surface?

Make sure you understand how tidal heating works, too. Figure 23-8a [=14-8a in the 9th ed.] will be useful for understanding part of the story, but you also want to make sure you understand how *resonances* between moons can keep a moon's orbit elliptical. Looking at the discussion that starts at the end of p. 515 will probably be useful. (This discussion can be found in the first four paragraphs on p. 310 of the 9th edition.)

What is *Europa*'s surface made of? What might be underneath this crust (something that has planetary scientists all excited)? What is the evidence for this? How does tidal heating play a role in this story?

(It's possible that in class, I may have talked about some recent observations suggesting that *Europa* has something very special that's similar to Saturn's moon *Enceladus*. What is this, and what does it imply about the previous item in this what2know list? Here's an article that gives some more details.)

What are *Jupiter's rings* made of? How do astronomers think they formed? (You'll probably find it necessary to read through the section on Jupiter's rings a couple of times, to dig out the hypothesis about how they formed.)

Next, we dealt with Saturn...

What are the main differences between the interior of *Saturn* and the interior of Jupiter?

Why does Saturn show somewhat less prominent cloud bands than Jupiter?

What is the *Roche limit*, and what does it have to do with the rings of planets like Saturn, Jupiter, Uranus, and Neptune? Is the Earth's moon inside or outside the Earth's Roche limit? How about the International Space Station? (You will probably want to look at the section on Jupiter's rings for a description of the Roche limit.)

What are *Saturn's rings* made of? How thick are they? What are two reasons why we know they're not solid discs? (One reason is observational, as we may have showed using the planetarium's projection system, and the other one is theoretical; make sure you know what James Clerk Maxwell said about the rings.)

What do `shepherd satellites' like Prometheus and Pandora do?

Saturn has many interesting moons, much like Jupiter. We probably didn't study all of them in detail, but we probably took close looks at *Iapetus*, *Enceladus*, and *Titan*.

What are two really weird things about Iapetus? (one has to do with the *albedo* of the surface, and the other has to do with the *topography*. What's a current hypothesis for the origin of the albedo oddity?)

What makes Titan unique amongst all of the moons in the solar system?

What is Titan's atmosphere made of? What is the temperature like at the surface - would it be a good place for life?

What is the crust of Titan made of? What kind of `lakes' does it have? What evidence is there for the flow of liquids over its surface?

What are some similarities between Enceladus and Europa? Do we see anything coming out of Enceladus that relates to this?

Chapter 24: Uranus and Neptune

(This is Chapter 15 in the 9th edition.)

Who discovered *Uranus*, and when? What was this person's `reward' for the discovery? Is it really fair to say that it was purely a matter of random chance or luck?
(You might enjoy this 4-minute Nova video about the `astronomical family' that made this discovery)

What makes Uranus different from Mercury, Venus, Mars, Jupiter, and Saturn, as `seen' from the Earth? (Hint: Think of the early astronomers, e.g. the Egyptians or the Greeks.)

What causes the atmospheres of Uranus and Neptune to look bluish-green in color?

We mentioned that Jupiter and Saturn are best referred to as the `liquid giants'. What is a reasonably accurate term for Uranus and Neptune? How are their interiors different from those of Jupiter and Saturn? (`The Interior of Uranus', on p. 539, will be particularly useful here. It's on p. 333 in the 9th edition.)

Make sure you understand the crazy inclination of the rotational axis of Uranus, and what it means for Uranus's seasons. Imagine what it was like on Uranus in 1986, when Voyager 2 flew by it. It was southern-hemisphere `summer' at that time. If you could have floated in the upper atmosphere of Uranus at that time, looking upward at the sky, what would the apparent motion of the Sun have been like from these three places at that time? (Figure 24-3 will be worth studying in some detail. It's Fig. 15-2 in the 9th edition.)

- The south pole
- The equator
- The north pole

How are the magnetic fields of Uranus and Neptune different from those of the other planets that have magnetic fields?

How were the *rings of Uranus* discovered? How are they different from the rings of Saturn?

We looked at some of the moons of Uranus, and we saw that the surface of the small moon *Miranda* was particularly crazy-looking. What are two ideas that have been proposed to explain its bizarre `chevron' and `ovoids'?

Then, it was on to Neptune (also in Chapter 24)...

(… in other words, also Chapter 15 in the 9th edition…)

How was Neptune discovered? What role did mathematics and Newton's Laws play in the discovery?

How is Neptune's atmosphere both similar to and different from Uranus's?

What's strange about the orbit of Neptune's large moon *Triton*?

What's the surface of Triton made of? What process probably goes on there, which is similar to a process on Earth, but occurs at much lower temperatures? (In class, I may have used an imaginative analogy using the story of an encounter between us and a theoretical [and very unlikely] species of intelligent `Tritonians'.)

Chapter 25: Meteorites, Asteroids, and Comets

(This is Chapter 16 in the 9th edition.)

Where do we find most of the *asteroids* in the solar system? (Note: That question doesn't mean `where do we find meteorites on Earth, which is shown in Fig. 25-1 [= Fig. 16-1 in the 9th ed.].) What are asteroids generally made of?

Why are there gaps in the *asteroid belt*? (Figure 25-9 will be useful here, as will the `Kirkwood' story on p. 567. These are Fig. 16-9 and p. 361 in the 9th edition.)

What are *Apollo objects* and *NEO*s?

Are the asteroids really the remnants of a disrupted planet, or is there some other explanation for their origin?

What has the Dawn mission discovered about the asteroids Vesta and Ceres?

Astronomy 4

Section 1 (M through F, 8:30–9:20 am)

Test 1 | Test 2 | Test 3 | Material after Test 3

After Test 3, we covered these chapters:

Chapter 25 (Meteorites, Asteroids, and Comets) [It's Chapter 16 in the 9th edition.]

Chapter 24 (The portion about the Kuiper belt) [It's Chapter 15 in the 9th edition.]

And finally, some material from Chapter 19 about extrasolar planets. (This is from Chapter 10 in the 9th edition.)

Material from these chapters is on the Final Exam. Don't forget that the final exam is, by contractual agreement with the 4-year schools to which most of you will be transferring your credits, a *comprehensive* exam. This means it covers the whole quarter, so make sure to re-study the material from Test 1, Test 2, Test 3, **and** study this material from after Test 3.

Chapter 25: Meteorite, Asteroids, and Comets

(This is Ch. 16 in the 9th edition.)

What are the differences between a *meteor*, a *meteoroid*, and a *meteorite*?

If you were to watch meteors during a *meteor shower*, why would they seem to come from a particular *radiant point* in the sky? Would it be very likely that these meteors would hit the ground?

What are the major categories of meteorites?

How do the meteorite categories (at least some of them) relate to the internal structures of asteroids? (Figure 25-2 will be helpful here. It's Figure 16-2 in the 9th edition.) What are *chondrules* and *CAI*s? How do chondrites relate to the formation of the solar system and the solar nebula? (It will be worth carefully studying the story of the *Allende meteorite* on p. 563 [= p. 357 in the 9th ed].)

If you're looking at a *comet*, what (if anything) does the *tail* tell you about its direction of motion? What causes the tail of a comet, anyway? (The two-page spread on p. 574-575 has some particularly useful diagrams and explanations. It's on p. 368-369 in the 9th edition.)

What are the *coma* and *nucleus* of a comet?

What is a comet made of? How is this different from an asteroid?

Where do comets come from in our solar system? Make sure you're clear on the differences between the *Kuiper Belt* and the *Oort cloud*.

What has the Rosetta mission discovered about comet 67P Churyumov-Gerasimenko?

We probably watched a video about asteroid impact hazards. Here are some things to know about this topic:

Why weren't astronomers able to see the 2013 Chelyabinsk meteor coming?

In what way was the path of the incoming meteor a piece of (relatively) good luck? How could a different path have made things worse?

Where (in the solar system) would be a good place to put a space telescope, if your goal is to use the telescope to look for asteroids that might hit the Earth?

What part of the electromagnetic spectrum would be most useful for finding hazardous asteroids with this telescope?

What are some of the strategies that have been proposed for protecting the Earth from asteroid impact hazards?

Chapter 24: Uranus, Neptune, and the Dwarf Planets

(This is Ch. 15 in the 9th edition.)

Why did Percival Lowell suspect that there was another planet beyond Neptune?

How was *Pluto* found? Did it match Lowell's prediction?

How is Pluto different from the other outer planets? What was the debate about whether or not to call Pluto a planet? (It is particularly useful to understand the idea of a planet `clearing its orbital lane', as discussed at the end of p. 555 and the beginning of p. 556 - look for the analogy to an `oligarch'. [This is on p. 349 in the 9th edition.])

What is the *Kuiper belt*? What's an example of a Kuiper-belt object that's about the same size as Pluto, but is more massive?

Make sure you know the major findings that we discussed in the lecture about the Pluto New Horizons mission.

Extrasolar Planets (material from Chapter 19 [= Ch. 10 in the 9th ed.])

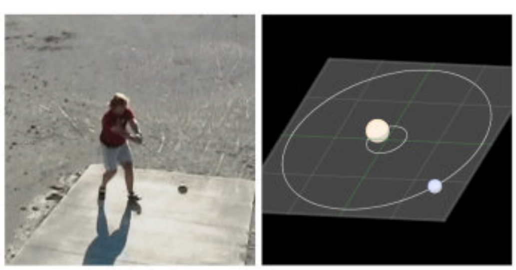
What are the challenges that make it difficult to detect planets around other stars?

How do *debris disks* around other stars relate to extrasolar planets? (The section on `Planet-Forming Disks' will be worth studying in detail here.)

How does the Doppler shift work? (It may be worth going back to p. 135 in Chapter 7 to review this. It is on p. 139 in the 9th edition.)

How is the Doppler shift used to measure the `wobbles' of other stars, and how does that allow us to detect exoplanets? (There was an analogy involving a person walking a dog. This analogy was used in the textbook (see Fig. 19-16, or Fig. 10-16 in the 9th edition).

There are some UNL simulations that can help to understand the Doppler method. The first is a simple video - the `Hammer Thrower' simulation:



If you're feeling ambitious, you could play around with the radial velocity simulator from UNL. This is one of the complicated simulations, though, and we do a whole lab with it in Astronomy 15L!

What are `hot Jupiters'? Why are they something of a mystery, compared to `our'

Jupiter?

How does the `transit' method of detecting an exoplanet work?

What's the *Kepler mission*, and what was its original main goal? What's an example of a multi-planet system that it's found?

How does *microlensing* work?