**Astronomy 5 - Study Guide for the Final Exam**

Here is a guide to help you focus on the important aspects of the chapters of the text covering material from our coverage of the Nebular Hypoothesis on. Use this guide in conjunction with the PREVIOUS GUIDES, in-class Quizzes and the Review Questions, which are found at the back of each chapter. Study the figures (sometimes a picture is worth a thousand words, and is easier to remember). Don't save studying until the last minute! Remember that the Final Exam is COMPREHENSIVE, so use the previous guide as well (still available on the web site). **YOU MAY use a 3"x5" Notecard** (hand-written, both sides) for midterm exams, and a 5”x8” card for the Final Exam! Be prepared for me to check these before the exam, and please hand yours in with your name on it when you turn in your exam.

**Astronomy and the Universe**

What is the Scientific Method, as we discussed in class? Perhaps YOU could think of YOUR OWN example of how YOU practice doing science this way every day... We looked at some basic math tools and skills, such as the idea of Scientific Notation. The basic units of measure that we will use include mass, time, and length. Standard measures of Astronomical distances use units of A.U., lightyears, and parsecs. Standard metric prefixes that you should know include kilo-, milli-, mega-, giga-, etc. Many astronomical observations are also done using angular measures (definition of a parsec, for example). Can you think of some pertinent questions on these topics? (if not, see the end of Chap 1!)

**Motions of the Sky, Phases of the Moon**

Positions, Celestial Sphere, Seasons There are several ways to pinpoint features of the sky. One way, a "local" way, uses terms like horizon, azimuth, altitude, zenith, nadir, and meridian. (I KNOW you know what these mean...) A more global view is the map of the sky that we call the Celestial Sphere, which is based on Earth's natural spherical coordinates (Equator, poles, period of rotation). What are Right Ascension and declination?

Earth has three important motions: Rotation, Revolution, and Precession. Further, some of these pertain to what part of the universe we can see at night, as well as to why we have seasons. Can you explain these different motions, as well as other important events (such as Solstices, Equinoxes) and the extremes on Earth that correspond? What marks the Celestial Sphere's North Pole? Has this always been, and will it always be? Why/why not? What is the ecliptic? Recognition of the constellations is a tool for remembering the locations of stars, allowing for humans to plan for seasonal changes. Oh, speaking of seasons, why does the Earth have them? Remember that this is a bit complex, and so a simple answer (e.g., "the Earth's axis is tilted") likely will NOT suffice!

We will have discussed the orbit of the Moon, and the resulting phases. Could you identify the lunar phase (using the proper words, of course!) if you were shown the Earth-Moon-Sun configuration? Could you identify the phase if you were shown a picture? What is an eclipse; what kinds are there; and when/why do they occur?

**Laws, Gravity, and Tides**

We will have discussed the evolution of thought regarding our perspective on the solar system and universe from two views, based on the historical progression of observations and ideas. Can you compare/contrast the basic ideas of the Geocentric vs. Heliocentric models? Summarize the relevant contributions of these people: Aristotle, Eratosthenes, Ptolemy, Copernicus, Brahe, Kepler (3 laws!), Galileo, and Newton (4 laws!). [Once these contributions were available, we could build a framework for understanding the origin of the solar system, called the Nebular Hypothesis. We will be addressing this important hypothesis later.] How does Gravity work, according to Newton? What do you know about the difference between a scalar and a vector quantity? Can you give examples?

Explain the cause for the tides in Earth's oceans, and what must happen (and when) for Spring and Neap tides to occur. Include the influences of all players, especially in light of Newton's 3rd Law of Motion!

**The Nature of Light**

We reviewed some of the properties of light that were once thought to be contradictory: reflection, refraction, diffraction, interference, and the photoelectric effect. Can you describe each of these, and tell whether it indicates light's wave-like or particle-like nature? Light (as we normally use the word) is actually only a small fraction of a much larger continuum of radiation known as the Electromagnetic Spectrum (EMS). The EMS has been subdivided into different regions, such as those with the shortest wavelengths and therefore highest energies (as dictated by Planck's Law), called gamma rays, and those with the longest wavelengths and lowest energies, called Radio waves. What are the others? What are the colors that make up visible light, and what are their relative energies? Important Laws to know include Planck's (E = hc/λ), Wien's, Stefan-Boltzmann, Kirchhoff's Laws governing blackbody radiation can be "boiled down" to read something like this: 1) All objects emit radiation (from their surfaces). 2) Hot objects emit more energy than cold objects. 3) Hot objects emit higher energy radiation than cold objects. 4) Photons are generated or absorbed when a charged particle, such as an electron, is accelerated. A REALLY important concept here is that the Bohr model of the atom explains the absorption and emission spectra of atoms. What kinds of substances/conditions produce continuous, absorption, or emission spectra? (We discussed Absorption at length in class.) Can you explain why each case should happen?

**Telescopes**

Reflection and refraction are important properties to consider when building optical telescopes. You should be familiar with parts and relationships, such as the objective lens, eyepiece, and focal length, and how these affect light-gathering power, angular resolution, and magnification. You should also be aware of potential problems (spherical and chromatic aberration, weight, temperature, etc.) and how reflectors avoid those problems! For reflecting telescopes, can you tell the differences among the four varieties we discussed? What are the practical applications of each of these (who would use it, and why)? Astronomers and astrophysicists use a variety of other kinds of telescopes to capture the photons from all other parts of the EMS too. Why are some telescopes useless at Earth's surface - why is it necessary to send them into space?

**Comparative Planetology**

This section involves both obtaining and also using some basic data regarding the objects in the solar system - data that can constrain how we think the solar system formed and how it has evolved since its formation. Some of the broad points that need to be considered are data you should have a handle on, and should include averages and extremes. For example, what are the three basic categories of materials that we started with, and why are they divided up that way? We have classified the planets into Terrestrial (T) and Jovian (J). What are the bases for this classification? One is their size: T are small (how big in diameter? which is biggest/smallest?) while J are huge (again, what is the ballpark for their size, and which is biggest/smallest?) Another is density (which is… what?) Why is density an important property to consider? It is not merely interesting that ALL the planets (which Pluto is not!) orbit in the same plane. Why do you suppose Mercury is out of that plane by 7 degrees? They also revolve in the same direction. Do they all rotate in the same direction? What about moons (revolutions and rotations)?

The Nebular Hypothesis for the Origin of the Solar System is a time-tested framework for our understanding of the Solar System. Can you describe the steps (as we did in class) involved, from the formation of the nebula itself (long after the Big Bang - you shouldn't need to discuss the Big Bang anywhere yet in this class) up to the (relative) present? Where did the particles come from? Why did they hang around for so long with nothing happening? Why might that stability have changed, resulting in the formation of the Solar System as we know it? How did the formation of our star and planets proceed? What forces were involved? (Hint: the Sun is not a force!) More specifically, what is the Solar Wind - where does it come from, what's happening, WHY is it happening, and what does it do? (Hint: the concept of the T-TAURI STAGE should figure prominently here.) Lastly (kind of!), does this model explain the formation of the objects in our solar system? In other words, what components of the hypothesis satisfy the similarities and differences observed in the planets today?

**Planets and Their Satellites**

Be able to identify the important feature(s), on which planet they are found, and to which planet does a particular moon belong? What does that feature tell us about the history/evolution of that planet/moon?

**Dwarf Planets, Comets and Meteorites**

What other kinds of objects are in our solar system? Describe their basic compositions and most likely areas where you might expect to find each. How does one find an **asteroid**? Are they ALL in the Asteroid Belt? Are we in danger of encountering any? What is really expected to happen if a large asteroid strikes (as one did about 65 M.y. ago) – will it kill us?

Label the parts of a **comet**. Does the bright (most visible) ion tail tell us the direction the comet is traveling? Does the dust tail? Explain the events that happen as a far-away comet comes in close to the Sun, then shoots back out again. Why might a comet break up?

**The Sun - Our Star**

The Sun is a typical star. Can you state a few intelligent reasons why it is important for us to study the Sun? Since fusion is creating such a powerful *outward* force (radiation pressure), what holds the Sun together? From where - and by what process - is that energy derived that makes fusion possible? What is the importance and probability of the "proton-proton chain?" Why does this complete reaction only occur when temperatures and pressures are so incredibly high?

What are the internal layers of the Sun, and what happens within each to the energy that is trying to get out of the core? (In other words, why is it that gamma rays produced by nuclear fusion end up as Visible Light at the "surface?") What are Neutrinos, and why are they so difficult to understand? What kinds of features are observed in the Photosphere and Chromosphere?

What is the Solar Wind, and why should we know about it - how does it affect different kinds of objects, including humans? What is the Solar Cycle, and why is it relevant? Where are we right now within that cycle?

**Nature of Stars**

It is important to think about the stellar properties that we can measure, especially the important ones that tell us something about the processes occurring inside them and how stars may change with age. Important properties include their distance, brightness, luminosity, color, temperature, mass, and size; all but one of these can change dramatically over the life cycle of the star! The other might change drastically during the dramatic “death scene…”

We can determine the distance to a relatively near star using parallax - explain exactly how this is done! Can we use light-years to measure that distance? (Or must we determine using parallax, and then CONVERT to light-years?) What is the importance of the A.U. in this technique? What is a parsec? How do A.U., light-year and parsec compare? It is currently possible to use the parallax method to measure the distance to an object that is up to 150 pc away! [Are there any other ways to determine the distances to stars? (The simple answer to this is, of course, "Yes!" but I think you might suspect that I might ask you what other ways there are, don't you? Those other ways can be found in various units...)]

How does distance affect brightness? What are the apparent and absolute magnitude values for the Sun? What is luminosity, and how does it relate to brightness?

Recall from our discussions about Blackbody Radiation that the surface temperature is related to the variation in intensity of wavelengths - the "intensity or solar curve." We can also determine surface temp. via "stellar spectroscopy." Can you give a brief run-down on how this technique works? What are the spectral classes of stars, and what are the characteristics of each spectral class? Remember that little bit about subclassifications - what is the complete spectral class and subclass of the Sun?

The way that the properties of Temperature and Luminosity (or Absolute Magnitude) change with age can be demonstrated on a Hertzsprung-Russell Diagram. Label these star fields on this type of diagram: red and white dwarf, red giant/supergiant, main sequence. How do they relate to various solar radii? How about solar masses? What is the general relationship between mass and luminosity - does it apply only to CERTAIN stars? What about luminosity classes - what type is the Sun? Gosh, that H-R diagram - what an incredibly useful diagram, don't you think?!

**Lives of Stars - Birth to Middle Age**

What is in between stars - is space ALL a vacuum? What else is there - what are some major components that we can detect in the interstellar medium (ISM)? [Note that there is theoretically more out there than we can detect - such as "virtual particles" and Dark Matter] The particles in the ISM are sometimes more tightly packed (even though they're still not too close to one another!) into regions known as Nebulae or Molecular Clouds. These loose concentrations of material can hang there in space for millions – BILLIONS – of years, representing some unchanging form of stability. **Jeans Instability** represents the moment when the gases and dust making up some portion of a nebula begin to collapse inward due to gravitational attraction. What must happen in order for a portion of a giant molecular cloud to collapse to form a star? What determines whether a lone star forms, or an accretionary disk with planets?

MASS is important in determining the evolutionary path that the star will follow. Describe the sequence of events (nebula, protostar, pre-main-sequence, main sequence) and the time frames for the development of stars of EACH of these masses: very low-mass, low- to medium-mass, high-mass. Which is our Sun? What happens to the position through time on the H-R diagram? Emission nebulae are prime locations for stellar birth - Stellar Nurseries.

What happens to mark the onset of "adulthood" - the Main Sequence Stage? WHY do the processes that operate during this stage result in a balance? Fusion is a process that releases energy. What are some of the fusion reactions that occur (for example, H to He, "CNO," etc.), and why does fusion release so much energy? How are the internal processes different among stars of different masses? How do the processes **change** throughout the Main Sequence (e.g., shell fusion, etc.)? The result might be a Red Dwarf, or a Red Giant, or a Supergiant. Where do these plot on the H-R diagram?

**Deaths of Stars**

Now that the star has "lived its useful life," fusion is on the verge of ending. How much mass there is, and how much is left, determine what will become of the materials that make it up. Recall that during the progression to the Giant stage, mass is continually being lost. If there was very low mass to begin with, the inward force of Gravity may not be sufficient to sustain fusion reactions, and the star will simply "fizzle out" and collapse into a red or brown dwarf. Otherwise, successive fusion reactions in the core may occur if and when the products of previous fusion build up enough, increasing the pressures and temperatures there. (We didn’t cover this part in depth, but such renewed fusion reactions may produce a temporary stability - "horizontal branch" on the H-R diagram, which then evolves to the Asymptotic Giant Branch. These "variable" stars pulsate in brightness. As fusion products continue to accumulate, fusion processes may accelerate in a "thermal runaway" effect similar to the He-Flash.) This could cause a significant expulsion of mass, an event producing a Planetary Nebula.

What happens to the material that gets ejected from the star? What happens to the material that remains? The mass of a star determines the size of its Roche Lobe - which can be teardrop-shaped for binary stars. Note that these are very important in our understanding of Supernovas and other phenomena! Sometimes what remains collapses into a hot, dense ball of non-fusible material collectively called a White Dwarf. Such an object might simply radiate its heat away over time, eventually cooling to a black dwarf. Another, more complex set of circumstances are created in a binary system. What is a Nova, and why might it occur? What about a Type Ia Supernova?

On the other hand, what if the Chandrasekhar Limit is exceeded? At what remaining mass (how many solar masses) would this occur? What is a Type II Supernova, and what are the products of such an energetic event?

Stellar remnants with more mass have two other options; they might become neutron stars or black holes!  What's so weird about neutron stars - what is their structure? What are Pulsars/Cepheids, and what types are there?

Black holes (BH) defy our perception of reality, but Einstein broke through that mold and gave us his Theories of Relativity. What are the basic ideas around these theories? Why are they necessary - don't we have enough laws to cover physics without them? What are some (relevant) predictions of these theories? For example: what happens to light near a BH? We can use these theories to search for evidence for BHs. What evidence have we found? What IS a BH, what properties might they have, and what kinds are there supposed to be? Are they all supposedly formed the same way? What happens as you get closer and closer to the event horizon? Are they forever, or can they somehow decompose? Explain. Then rest so your head can return to its original size and shape (hopefully you've done this BEFORE exam day!)

**Galaxies**

Galaxies are collections of all the things we've been talking about. It seems logical that most are centered around massive or supermassive black holes, and recent observations tend to support this logic.

What do you think you're supposed to know about our OWN Galaxy - BESIDES its name? Can you answer your own questions? Here are some suggestions, just in case ;-) : How big is it? What is its shape, and what are its features? Where is most of the mass - or how is mass distributed within the MWG? Describe the different kinds of nebulae in the ISM (Interstellar Medium). What kinds of complications do we run into when we try to observe other galaxies? Is there some relationship among these complications - do they share a common root? Is there any way to overcome these problems – say, by looking in different wavelengths?

Describe the essence of the Shapley-Curtis Debate, and what eventually decided who was correct. How do we measure distances to objects whose parallax is too small to measure (since they are > 150pc away)? (Hint: Hubble is not just the name of a telescope!)

What are the classes and subclasses of galaxies? *Could you identify them from pictures*? (***Pictures of objects will appear on the final***!) How does the shape of a galaxy vary in 3 dimensions, or do we know that? What is a Nuclear Bulge, and what's inside it? How do the spiral arms of spiral and barred galaxies evolve? What might cause the irregular patterns in those galaxies?

What's happening in galaxies - are they fixed in space? Since the stars inside a galaxy are moving, I suppose it's important to understand HOW they move so that we can figure out how the shape of a galaxy might evolve. So: how does the orbital velocity change, as a function of distance from the nucleus? What's "wrong" with the relationship – does the relation obey Kepler’s 3rd law, or not - and what does that tell us about the make-up of galaxies?

Are galaxies the biggest things out there? How are the galaxies in a cluster related to one another - and why do we think they are not as related to other galaxies in other clusters? Describe the relationship known as Hubble's Law. Why is it important?

**Cosmology**

What is cosmology, and what does it seek to cover?

Remember that Hubble's Law and Hubble flow indicate an expanding universe. The fact that the Universe is expanding gives us ways to detect its age (how so? Recall that we did this assuming constant velocities for distant galaxies, although different galaxies can have velocities that are different from others). In other words, how is H0 related to the age of the universe?

Think about the sequence of events that must have transpired during the first moments of the Big Bang. The four fundamental forces of nature are Gravity, Electromagnetism, the Strong Nuclear Force, and the Weak Nuclear Force. When did they come into existence? Why is the Planck Time of interest to theorists? Why is it that there was a time when the electromagnetic force did not exist as such?

What will happen to the universe, in the future? Will it end, collapsing after it finally reaches as far out as it will go, will it continue to expand indefinitely, or is there something else discussed in your book? HOW DO WE KNOW?