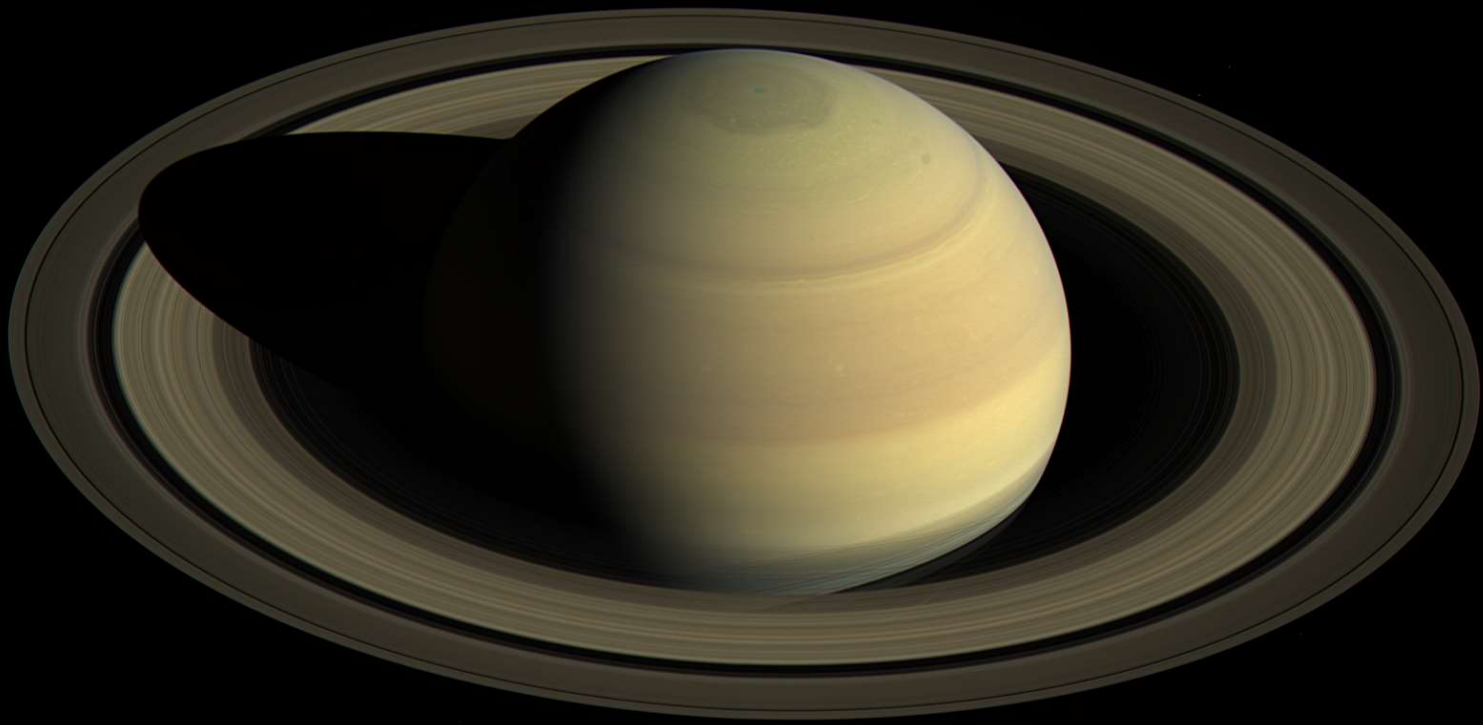
AST 2002
Introduction to Astronomy



A Few Quick Things…

E-mailing me: Must have AST2002 in the subject

Mary Hinkle, Graduate Teaching Assistant:

Office hours: Mon 1:30-3:00pm. PSB 316

~~My office~~ hours: Mon 3:00-4:00pm. PSB 316

(Amy in PSB316) Tue 3-4 pm. PSB 316

I will be in DC next week afterwards… Mon-Thur

Amy will be covering my office hours next week. I will try to be available Mon morning.

I will be going through the iClicker results Next Friday – Tuesday on an individual basis.

Curved Mid-term results are out on webcourses...

Homework is also out (next slide)

Final: Friday 27th April. 7am-9:50 am. (on all chapters; ~ 100 questions. 25:25:25:25)

LAST Knights Under the Stars Event – WAS Thursday 19th April

Opportunity to make up the 1% extra credit that was offered (if you haven't been yet, worth 2%) ***– Last chance for extra credit..***

Homework (Revised) & Evaluations

There are 3 homework sets on Webcourses:

- HW # 2 is on Chapters 1-5, 15 questions, due April 27th at midnight
- HW # 3 is on Chapters 6-9, 12 questions, due April 27th at midnight
- HW # 4 is on Chapters 10-13, 12 questions, due April 27th at midnight
- The Syllabus quiz has been re-opened and will be available until April 27th at midnight
- HW #1 has been re-opened and will be available until April 27th at midnight

Each quiz is worth 2%. The syllabus will be worth 1% and there will be a bonus 1% for putting up with the 'lack' of homework throughout this course…

Evaluations of the Course & Instructor are available on Webcourses – Please fill out this week!

The Exam… what to expect

Exam will be in Class in THIS ROOM on Friday 27th April 2018

- When you come in, please make sure you have plenty of space when you chose a seat

Do Bring:

- Scantron

https://ucfsga.com/services/free-scantrons-and-blue-books/

- Pencil (2B or #2 recommended)
- Make sure you know your PID
- Scientific Calculator
- An ID – you will need your ID to hand in the exam.

Don't Bring:

- Books, notes, or phones

The Exam… what to expect

- **The Exam will consist of 100 multiple choice questions.**
- **There will be 4 sections corresponding to ~ the same structure as the exams**
  - **Part I will be chapters 1-5 (25 questions)**
  - **Part II will be on chapters 6-9 (25 questions)**
  - **Part III will be on chapters 10-13 (25 questions)**
  - **Part IV will be on chapters 14-19 (25 questions)**
- **There will be matching questions and true or false questions in each section**
- **There will be minimal math questions…**
  - ***BUT – be prepared for doing some math, particularly in section I (chapters 1-5)***
- ***Some of the questions you will have encountered before!***

It will be based mostly on the lecture content BUT the general knowledge questions may rely on content within the books

THIS GUIDE MAY NOT COVER ALL THE MATERIAL THAT MAY BE ON THE EXAM, FOR THAT YOU SHOULD COVER ALL LECTURE MATERIAL AS WELL AS THAT FROM EITHER TEXT BOOK!!

Some material only covered in class could be on the exam…

Study Guide – Chapter 1

Topics, lecture slides:

- **Common distances used in astronomy, ch1_pt1 slide 8**
  - **Know how to calculate how distances light travels in time; see ch1_pt1 slide 6**

- Features of the Solar System, ch1_pt1 slides 13-19
  - **Can you tell the Kuiper Belt from the Oort cloud?**
  - **Can you name the planets, in order of increasing distance from the Sun, and tell me why Pluto isn't one?**

- Our Place in the Milky Way, ch1_pt2 slides 4-7
  - What is the nearest star?
  - What is our place in the Milky Way?
  - **What is the name of the black hole in the center?**

Study Guide – Chapter 1 cont.

- Our Place in the Universe, ch1_pt2 slides 8-15
  - How big is the Universe?
  - **Are we seeing galaxies as they are now, where they are now or where they were back when the light reaching us now left them?**
- Spaceship Earth, ch1_pt2 slide 16
  - Understand how you are moving on the Earth and how the Earth is moving through our Solar System and through space
- The Cosmic Calendar, ch1_pt2 slide 18
  - **how old is the Universe?**
  - **how old is the solar system?**
  - **how long ago were the dinosaurs killed?**
  - **how long has known human civilization existed?**

Study Guide – Chapter 2

- Describing locations on Earth and in Space ch1_pt2 slides 22-23
  - Longitude and Latitude, Declination and Right Ascension

How Earth Rotates ch1_pt2 slides 25-26

- **what is a sidereal vs. solar day? see also ch2_pt2 slide 11**
- what direction does the Earth rotate? - Sunrise vs. Sunset

Celestial Poles and Stars ch1_p2 slides 28-31

- **how is Earth tilted?**
- **what are circumpolar stars? See also ch2_pt2 slide 27**

Measuring angles in the sky ch2_pt2 slides 8-9

- How many degrees approximately is a fist? A finger?

Study Guide – Chapter 2 cont.

- Celestial and Ecliptic planes, ch2_pt2 slides 12-13
  - What is the equinox so important?
  - **What is the ecliptic plane?**

How the sky at night changes, ch2_pt2 slides 14-28

- **slide 14 is important to understand..**
- **How does it differ at the poles versus at the equator? i.e. what stars/constellations can you and can't you see?**

What are seasons? ch2_pt2_slides 29-33

- also ch2_pt3 slide 12
- **seasons are due to tilting, not planetary distance - see ch3_pt2 slide 13-14**

The constellations, ch2_pt2, slide 23 (watch videos), slide 24, slide 36

- also ch2_pt2 slides 3-4
- **be able to determine which constellations are visible the Sun is 'visiting' at time of year**

Study Guide – Chapter 2 cont.

The Phases of the Moon ch2_pt2 slide 34

- **also ch2_pt3 slides 13-16 (slide 13 is very important)**
- **be able to identify phases of the moon (waxing vs. waning)**
- **should be able to determine when each phase of the moon is visible**
- **example in ch3_pt1 slides 2-4**

Eclipses, ch2_pt3 slides 17-20, 24-27

- what are nodes? Umbra/Penumbra?
- conditions for solar eclipse, lunar eclipse

Calculation – How BIG are things? Ch2_pt3 slides 22-23

Study Guide – Chapter 3

The motions of the Planets, ch3_pt1 slide 5 (watch videos)

- **heliocentric *vs.* geocentric views**
  - **how do both explain retrograde motion?**
  - **why wasn't geocentric model accepted?**
  - **what is parallax?**
  - why is it difficult to believe the Earth is moving?

Calculation of distance to stars, ch3_pt2 slides 16-17

- **should be able to calculate a distance given an angle (in arc seconds)**
- **should be able to calculate an angle given a distance**
- **remember 1 parsec = 3.26 light years!**

What was the role of each of these astronomers? see also ch3_pt2 slide 4

- **Claudius Ptolemy, ch3_pt1 slide 10**
- **Copernicus ch3_pt1 slide 29-30**
- **Tycho Brahe ch3_pt1 slide 31**
- **Johannes Kepler ch3_pt1 slide 33**

Study Guide – Chapter 3 cont.

Kepler's Laws - ch3_pt2 slides 5 – 19

$$e = \sqrt{1 - \left(\frac{b}{a}\right)^2}$$

1st law: bodies move in elliptical paths

- be able to determine eccentricity from semi-major axis and focus
- be able to determine eccentricity from semi-major and semi-minor axis
- Why is semi-major axis so important (ch3_pt2 slide 9)
- What are perihelion and aphelion?

2nd law: As a planet moves around its orbit it sweeps out equal areas in equal times

- Bodies in orbit will speed up as they get closer to the Sun
- Be able to relate velocity to perihelion/aphelion

3rd Law: More distant planets orbit at slower average speeds. $p^2 = a^3$ (ch3_pt2 slide 15-17)

- Given an orbital period should be able to calculate distance from Sun
- Given a distance from the Sun, should be able to calculate an orbital period

Study Guide – Chapter 3 cont.

The importance of Galileo, ch3_pt2 slides 20-27

- Showed that objects in motion stay in motion unless a force acts on them
- Used telescopes to show heavenly imperfections (sunspots, mountains and valleys on the Moon)
- Used telescope to determine that there were many stars in the milky way
- Showed that there were other moons in orbit around other bodies (Jupiter's Moons)
- **Observed all of the phases of Venus.**

    - **How does this prove heliocentrism? ch3_pt2 slide 27**

What are the hallmarks of Science? ch3_pt2 slide 32

Study Guide – Chapter 4

Newtons Laws of Motion ch3_pt3_ch4_pt1 slides 19-23

1st law: object in motion will not change its course unless a force acts upon it.

- Understand relationships between position, velocity, acceleration and jerk.

2nd Law: Net forces cause a change in the motion of an object, F=ma

- **Centripetal forces, ch4_pt2 slides 5, 10-11**
- **Mass and Weight**
- **understand the difference between mass & weight ch4_pt2 slide 14**
- **understand how acceleration affects weight ch4_pt2_slide 17, ch4_p4 slides 6-7**
- **be able to explain why people experience weightlessness in orbit**
    - **in constant free-fall.**

3rd Law: For every force there is an equal and opposite reaction force.

- Example – rockets

Study Guide – Chapter 4 cont.

Importance of the Inverse square law ch4_pt2 slide 12, 13

- **Be able to use this to explain changes in Force or Light intensity over distance**

What are momentum and inertia? Ch4_pt2 slides 20-22

- Be able to determine qualitatively how much an object has based on mass and velocity

Newtons Law of Gravity Ch4_pt2 slides 23-29

- **Acts as $1/r^2$ (inverse square law!)**
- **Newton's version of Kepler's 3rd Law. ch4_pt2 slides 24-25**
- Bound and unbound orbits (ch4_pt2 slide 26)
- What are gravity assists, and how do they work?
- That each planet has an escape velocity required to break orbit
    - Not based on mass, which leads to understanding why H/He on larger planets

Study Guide – Chapter 4 cont.

Tidal Forces ch4_tidal_forces_ch5_pt1 slides 8-13

- Moon and Sun can act in tandem or against each other

spring and neap tides ch4_tidal_forces_ch5_pt1 slide 10

- Moons influence on the Earth causing tides ~ every 12 hours
  - why slightly more than 12 hours?
- Earth's influence on the Moon, synchronous orbit so same side always faces us.
- Transfer of angular momentum from Earth to the moon
  - Earths rotation is slowing
  - The Earth-moon distance is increasing

Study Guide – Chapter 5

The relationship between frequency, wavelength and speed of light

- Should be able to calculate wavelength/frequency and what happens to one when the other is changed (e.g., doubled), $f \lambda = c$ (ch5_pt1 slide 22)
- Relationship between frequency and energy, $E=hc$ (h is Planck's constant) c (ch5_pt1 slide 22)
- Red-shifted and blue-shifted terminology (how does this affect frequency, energy, wavelength?

What is Matter?

- Know that an atom is made up from protons, neutrons and electrons ch5_pt1 slide 23
- Know that isotopes have different numbers of neutrons. Ch5_pt1 slide 24

Light-matter interactions ch5_pt1 slide 29-31

- absorbed, transmitted, reflected, scattered and emitted light ch5_pt1 slide 29-31, ch5_pt2 slide 36

Study Guide – Chapter 5 cont.

- know that energy levels in atoms and molecules are quantized & have discrete transitions at specific wavelengths, e.g., ch5_pt1 slides 32-35
- it takes more energy (shorter wavelength) to interact with different transitions...
  - radiowaves and microwaves = rotations
  - infrared light = vibrations (thermal energy, heat)
  - visible light - electronic excitations
  - UV light and X-rays - bond splitting and ionization ... all on slide 26
- know the order of these light waves, ch5_pt2 slides 13-14

Continuous spectra

- Stefan Boltzmann law for determining energy given temperature (or vice versa)
- Wien's Law for determining average wavelength given temperature (or vice versa)
- Understand that for an increase in temperature, more light and blue-shift
- All bodies heated up have a ~continuous close to 'black body' spectrum
- As objects are heated they emit more light, ch5_pt1 slide 36

Study Guide – Chapter 5 cont.

absorption spectra

- Earth's atmosphere is an example, so are clouds of dust in space
- Will occur as dips in the continuous spectrum where light is removed (absorbed)

emission spectra

- Will appear as additional intensity on top of the continuous spectrum
- Will need to be populated by some condition (e.g., high temperature)

The doppler effect

- What is the doppler effect?
- How can we use this to determine velocities
- Based on change in wavelength should be able to determine whether object is moving away or towards us.
    - Note the sign. Think about it. Limited to Radial information to/from us

Study Guide – Chapter 5 cont.

Telescope design

- Know the difference between refractor and reflector telescope
- Light gathering power: What is it, why is it important?
- Resolving power: What is it, why is it important?
- Magnifying power: What is it, why is it important? Or not as important…
- Interferometry - helps with resolving power for radio telescopes.
- **Why put telescopes in space?**
- **1. Less light pollution**
- **2. No atmospheric absorptions**
  - **This is worst for UV/X-rays and bad for IR and gamma rays**
  - **but isn't really a big problem for visible and radiotelescopes**
  - **changes in air density (can be improved using adaptive optics)**

Study Guide – Chapter 6

- **A Brief Tour of the Solar System, ch6_pt1 slides 6-22**
  - **Know the main features of the solar system**
    - **Planetary distances, densities, temperatures, compositions**
    - **Asteroid belt, Kuiper belt & Oort cloud**
    - **The approximate size (mass), composition and temperature of the Sun**
  - **Can you tell the Kuiper Belt from the Oort cloud?**
  - **Can you name the planets, in order of increasing distance from the Sun, and tell me why Pluto isn't one?**
- **Trends across the Solar System, ch6_pt1 slides 23-24**
  - **How and why do the Terrestrial planets and Jovian planets differ?**
    - **Rings, moons, densities, formation conditions, compositions, etc.**
- **The formation of the Solar System,** ch6_pt1 slides 27-30, Ch6_pt2 slides 16-
  - **What are the general features of the Solar System that we must be able to explain?**
  - **What are the exceptions to the rules? And how can these be explained?**

Study Guide – Chapter 6 cont.

- What are some of the theories on Solar system formation? (can you explain Nebular Theory?)
  - Can you explain gravitational collapse, conservation of angular momentum, and why does it get hot and flatten out?
- **At what temperatures do metals, rocks, and hydrogen compounds condense and what proportion of the Solar Nebula are they?**

- **How did the Jovian planets form?, ch6_pt2 slides 26-34**
  - What are planetesimals?
  - **Why does the snow/frost line matter so much?**
  - What was the size of the cores of Jovian planets during accretion, and why did they grow to have different sizes and compositions? … what stopped them?

- Exceptions to the Rules, ch6_pt2 slides 35-37
  - What are the exceptions to the rules, and how can we explain them?
  - **What is the evidence for impacts?**
  - **What is radiometric dating and how does it work?**
    - Do you understand the process and calculation well enough to answer questions?

Study Guide – Chapter 7

- **The Terrestrial Planets, ch7_pt1 slides 14-19**
  - **What are some of the main features common to the terrestrial planets?**
  - What features are unique to each planet?
  - What is comparative planetology?

- Interiors, ch7_pt1 slides 20-45
  - What are S and P waves, and how do they inform us about the interior of planets?
  - **Why does size matter when it comes to internal heat sources?**
  - **What are the main heat sources for terrestrial planets?**
  - **Can you describe differentiation?**
  - How do bodies cool? – what is the role of surface area to volume ratio?
  - Why are large bodies round?
  - What are the different interior layers of the Earth and Terrestrial planets?

Study Guide – Chapter 7 cont.

- **Geological Processes, ch7_pt1 slides 46**
  - **Cratering Impacts and Surface ages**
  - Volcanism and outgassing
  - Erosion and its connection to wind/rain/ice
  - **Tectonics (and its relationship to climate stability on Earth)**
- **Magnetospheres, ch7_pt3 slides 5-6**
  - **What causes a magnetosphere on Earth (and on other planets?)**
  - **How does this interact with the Solar Wind?**
- Atmospheres, ch7_pt3 slides 7-11
  - What are the different layers of the atmosphere?
  - **How does the atmosphere protect us from radiation? – what radiation is let through? … why?**
  - **Why is the sky blue, and sunsets red?**
  - **What is the greenhouse effect? What gases are most important for this effect? Why?**

Study Guide – Chapter 7 cont.

- Mercury and the Moon, ch7_pt3 slides 12-13, ch7_pt2 slides 30-39
  - What is the evidence for geological activity on these bodies?
  - How long ago did it occur?
- **Mars, ch7_pt3 slides 15-17, ch7_pt2 slides 40-62**
  - **What is the evidence for past water on Mars?**
  - **Why did Mars change? What is the current theory about why Mars lost its water?**
  - **Is there water currently on Mars? If so, where is it?**
- Venus, ch7_pt3 slides 26-35
  - Evidence of geological activity on Venus?
  - What is the surface age of Venus?
  - **What is the runaway greenhouse effect?**
  - **How does the greenhouse effect compare for Earth, Venus, and Mars?**

Study Guide – Chapter 7 cont.

- Earth as a living planet, ch7_pt3 slides 38-58
  - Why is liquid water important on Earth, for life, and for geological cycles?
  - **Where did atmospheric oxygen come from, how do we know, and would we expect to find it elsewhere?**
  - **What are plate tectonics? And how do they help with climate stability on Earth?**
  - How do the plates evolve in time?
  - **What is the carbon dioxide cycle on Earth, and how does it work as a feedback loop for global warming?**
  - What is the evidence to support that humans are causing climate change on Earth?
  - What makes a planet habitable? – think of planetary size and distance as being two important factors.
  - W**hat is the role between planetary size, heat retention and the surface ages of terrestrial worlds?**

Study Guide – Chapter 8

- **Jovian Planets, ch8_pt1 slides 22-49**
  - **What missions have flown to the Jovian planets?**
  - **How, when, and where are the Jovian planets thought to form? Is migration a factor?**
  - **What happens to the size of Jupiter as you add more mass?**
  - **How do the compositions of the Jovian planets differ from one another? Similarity to the Sun?**
  - Do the Jovian planets have strong or weak magnetic fields?
  - Can we see their aurora? What is the connection between the magnetic field and their moons?
  - What are the atmospheres composed of, and how can we tell?
  - What is the weather like on the Jovian planets?
  - **What is Jupiter's Big red Spot?**
  - What is the relation between heat received and heat flux out of Jovian planets? Ch9_pt1_slide3

Study Guide – Chapter 8 cont.

- **Jovian Rings**, **Ch8_pt1 slides 37-40, Ch8_pt2 slides 68-70**
  - **All the Jovian planets have rings, but how do they differ in size, shape, composition?**
  - For Saturn, what are the causes of the gaps and what is so special about Enceladus?
  - What is thought to be the origin of the Rings?
- Jovian Satellites, ch8_pt2 slides 28-67
  - Why are the medium and large moons spherical?
  - **Where did the medium and large moons form? Are any of them captured objects?**
  - **What are Jupiter's Galilean Moons?**
    - **Io. What is the cause of its geological activity?**
    - **Europa – can you explain the surface features?**
    - **Ganymede – what can you tell me about this moon? How could it have a magnetosphere?**
    - **Callisto (see Ch9_pt1 slide 10)**

Study Guide – Chapter 8 cont.

- **Which moons of Saturn are interesting?**
  - **Titan – what is going on with all those hydrocarbons?? What did the Huygens probe tell us?**
  - **Enceladus – what is the source of the plume, and what is it doing at Saturn?**
- What are the main moons of Uranus?
- **Why it Triton so unique at Neptune?**
- **What is the reason that less heat is required for activity on the small moons and what is the origin of this heat in most cases??**

Study Guide – Chapter 9

- **Classifications, ch9_pt1 slides 34-37**
  - **What are asteroids?**
  - **What are comets?**
  - **What are dwarf planets?**
- **Meteorites, ch9_pt1_slides 38-51**
  - **What are meteors, meteoroids, and meteorites?**
  - **How to identify a meteorite**
  - Primitive vs. processes meteorites
  - **How do we know that meteorites originate from: a) Mars … or b) differentiating bodies**
  - What sort of things do we find in carbonaceous chondrites? What do these tell us about the early conditions of the Solar System? What else can we learn from meteorites?

Study Guide – Chapter 9 cont.

- **Asteroids, ch9_pt1_slides 38-51, ch9_pt2 slides 11-**
  - **Where are the asteroids located? How many are there?**
  - Why didn't a planet form in the asteroid belt, and how big would it be if it did?
  - **What missions have been to the asteroids? Which returned samples?**
  - How do asteroid compositions vary?

- **Comets, ch9_pt2 slides 28-38**
  - **What are comets? What are the main parts of a comet?**
  - Why do they start to grow tails? Why are there two tails, and where do they face?
  - **Where do short and long periods of comets come from? How can you tell?**
  - **Where did comets from the Kuiper Belt and Oort cloud originate from?**

Study Guide – Chapter 9 cont.

- **What is the association between comets and meteorite showers?**
- **What missions to comets have there been? Were any sample return missions? If so, what did they find?**

- Pluto and the Kuiper belt, ch9_pt2 slides 39-46
  - What can you tell me about the Pluto-Charon system? Size, moons, interiors, composition?
  - **Why is Pluto classed as a dwarf planet? … or as a Kuiper belt object? (or Trans-Neptunian object)**
- **Impacts, ch9_pt2 slides 48-62**
  - **What is the evidence for an impact wiping out the dinosaurs?**
  - **How frequent do large impacts occur on Earth? … in the Solar System?**
  - What is the role of Jupiter?

Study Guide – Chapter 10

10.1. Detecting Planets Around Other Stars

How do we detect planets around other stars?

- **Why is this challenging in the visible? [ch10_pt1_slide 5]**
- **What wavelengths make this easier? Why? [ch10_pt1_slide 12]**
- **What are the main techniques for detecting exoplanets?**
  - **Astrometric [Ch10_pt1_slides 6-9]**
  - **Transits [Ch10_pt1_slides 6, 13-17]**
  - **Doppler Shift [Ch10_pt1_slides 6-8,10-11]**
- **What is the difference between direct & indirect detection? [ch10_pt1_slide 6, example of direct slide 12]**
- **What are the bias of each technique? [also Ch10_pt2 slide 39]**
  - **Do we still think what we used to about Hot Jupiters? [Ch10_pt1_slides 6-23]**

Study Guide – Chapter 10 cont.

10.2. The Nature of Planets Around Other Stars

What properties of extrasolar planets can we measure?

- **What information can you learn from each technique? [Ch10_pt1 slides 6-23], [summarized in Ch10_pt2 slides 30-31, also see slides 25-26]**
  - **Size? Orbital Period? Mass? Radius? How do we get density?**
- **What spacecraft are used for each technique? [Ch10_pt2 slides 9, 15, 29]**
- **Approximately how many systems have been identified with each technique? [Ch10_pt2 slides 5, 16-17]**

How do extrasolar planets compare with planets in our Solar System?

- If you are given two properties of the orbital period, orbital distance, or mass of the star could you compare how the system would behave relative to that of our Solar System? [example Ch10_pt2 slides 32-33]
- **What are the range of densities and other properties observed for exoplanets? [Ch10_pt2_slide 34]**

Study Guide – Chapter 10 cont.

10.3. The Formation of Other Planetary Systems

Do we need to modify our theory of Solar System formation?

- **How would Hot Jupiters pose a problem for nebula theory? [Ch10_pt2_slides 36-38]**
- **What possible mechanisms for planetary migration could occur?**
  - **Stellar winds versus migration and cyclization of orbits. [Ch10_pt2_slides 36-38]**

Are planetary systems like ours common? [Ch10_pt1 slides 22-27]

- **How common in the universe are planets? Earth-like planets?**
- **How many lie in the habitable zone? [Ch10_pt2 slide 40]**
- **How does the habitable zone change with different types of stars?**
  - **How might it affect civilization and the origin of life if there were a high-mass star versus a low-mass star?? [Ch10_pt1_slides 23-25]**

Study Guide – Chapter 11

11.1. A Closer Look at the Sun

Why does the Sun Shine? [Ch11_pt1_slides 21-27]

- **The Sun is very luminous – how much energy does it output? What is luminosity? [Ch11_pt1_slide 21]**
- How long could chemical burning or gravitational contraction provide?
- **How old is the Earth, and how do we know this? [Ch11_pt1_slide 25]**
- **What is the source of the Sun's energy? [Ch11_p1 slides 27-37]**
- **What is the difference between nuclear fission and nuclear fusion?**
  - **Can you give examples of where both occur? [Ch11_pt1 slide 31]**

What is the Sun's Structure? [Ch11_pt1_slides 38-47]

- Approximately what is the temperature and density of the Sun as a function of radius? [Ch11_pt2_slide 21]
- **Can you describe where, the approximate temperature and density, and what occurs in the following regions? [ch11_pt1_ slides 38-47]**
  - **Corona, Chromosphere, Photosphere, Convection zone, Radiation zone, Core.**

Study Guide – Chapter 11 cont.

What is the Sun's Structure?

- What is the Solar Wind?
- How do we have evidence for convection on the surface of the Sun?

11.2. Nuclear Fusion in the Sun

How does nuclear fusion occur in the Sun? [Ch11_pt1_ slides 27-37]

- **How does the proton-proton chain reaction generate energy?**
  - **Why is a high temperature needed for fusion to occur? Coulombic repulsion?**
- **What else is produced from the p-p chain reaction? [ch11_pt1 slides 33-36]**
  - **Positrons – what happen to them?**
  - **Neutrinos – what happens to them?**
  - **Gamma rays – what happens to them?**
- **What is the solar thermostat, and how does it work? [pt2 slides 19, 22-24]**
- **How does the energy from fusion get out of the Sun?**
  - **How do neutrons and photons escape the Sun? How long does it take? [slide 12-13]**
  - What else do we know about Solar Neutrinos? What is the Solar Neutrino problem?

Study Guide – Chapter 11 cont.

- How do we know what is happening inside the Sun?
  - Observations of neutrinos reveal what? [Ch11_pt1_slides 47-49]
  - What other techniques are there and what do they reveal? [pt2 slides 29,31]

- 11.3. The Sun-Earth Connection [Ch11_pt2 slides 32-44]
- **What causes Solar activity?**
  - **How does the Sun rotate and how does this influence the magnetic fields? [39,42]**
  - **What is the 11-year cycle? What is the 22-year cycle? [32-39]**
- **How does solar activity vary with time?**
  - **What are Sunspots? When do they peak? [31-34]**
  - What are Solar Flares? [pt2_slide 37]
  - What are coronal mass ejections, and how can they interfere with Earth? [40,41]
  - How does the Solar Wind interact with Earth? [pt2_slide 42]
  - How does solar activity relate to global warming? Is there a link? [pt2_slide 35]

Study Guide – Chapter 12

12.1. Properties of Stars

How do we measure stellar luminosities? [pt1 slides 25-30]

- **What is luminosity? How does it vary with distance? [pt1 slides 25-30]**
- **What is apparent brightness? [pt1 slide 26-31]**
- **What is magnitude? What is apparent magnitude? [pt1 slide 31]**
- **What kind of variations do we observe for stars? [pt1 slides 22-23]**
  - **Which are most common? Are there any patterns?**
- **How can we use stellar parallax to measure the distance of stars? [30]**

How do we measure stellar temperatures? [pt1 slides 32-35]

- **Stefan-Boltzmann law (hotter bodies emit more radiation)**
- **Wien's law (maximum shifts to lower wavelengths for hotter bodies)**
- **Spectra are the best way to determine:**
  - **Temperature**
  - **Spectral type – patterns of molecules versus ions versus hydrogen lines… [35]**

Study Guide – Chapter 12 cont.

- **Spectral type – patterns of molecules versus ions versus hydrogen lines… [34-35]**
- **OBAFGKM series… remember this! [pt1_slide 36]**

How do we measure stellar masses? [pt1_slides 37-41]

- **What techniques? Are these similar to those for exoplanets?**
  - **What information is given by each?**
- Newton's formulation of Kepler's 3rd law… [pt1_slide 41]
  - **Given 2/3 of orbital period, radius and velocity we can determine mass of systems**
  - How? Easiest way is to compare to our Solar System [example, pt2_slide 13]
  - Plus using binaries (or binaries with another binary) to constrain masses…

12.2. Patterns Among Stars [pt2 slides 19-36]

What is the Hertzsprung-Russel diagram?

- **What is being plotted against what?? [22]**
- **Can you relate size & temperature to bodies on the H-R diagram?**

What is the significance of the main sequence? [22]

- **How does mass affect how long a star will stay on the main sequence? [23]**

Study Guide – Chapter 12 cont.

What are giants, supergiants, and white dwarfs?

- **Where are these located on the H-R diagram? [pt2_ 25-35]**
- **What can you tell about a star that is a giant? [pt2_ 25, what else??]**

12.3. Star Clusters

What are the two types of star clusters? [pt2_37]

- Which one (open or globular) would you use to better constrain the age of the Milky way? Why? [pt2_37]

How do we measure the age of star clusters?

- **What is the main-sequence turn off point? [pt2_38-40]**
- Be able to explain trends in terms of the life sequence of stars… [39.40]

Study Guide – Chapter 13

13.1. Star Birth

How do stars form?

- **What is the interstellar medium? [pt1_20-47]**
- **What are the conditions necessary for stars to form? [pt1 40-46]**
  - **Temperature? Density?**
- What features do we typically only observe with young stars? [pt 1 50-54]

How massive are newborn Stars?

- **What is the lower limit to the size of a star? Why? [pt1_56]**
- What is the upper limit to the size of a star? Why? [pt1 57-59]
- **What is degeneracy pressure? [pt1_ slide 58]**
  - **Does it depend on temperature?**
- **How do we categorize stars based on their mass? [pt2 slide 23]**
  - **E.g., based on life sequence, or interior, or internal processes**
  - Approximately same ranges for low, intermediate and high-mass…

Study Guide – Chapter 13 cont.

13.2. Life as a Low-Mass Star

What are the stages of a low-mass star? [pt2 slides 40-42 summarize]

- Hayashi tracks onto the main sequence… T-Tauri phase. [pt 2, 24-25]
- Main sequence… [pt2_slide 28]
- Red Giant Branch – broken solar thermostat. H shell burning [pt2 29-30]
  - What is the triple alpha process? What does it make, what does it not make? [31-34]
- Helium Flash – only in low mass stars where degeneracy pressure reigns. The onset of helium fusion… [35, 40 shows where on H-R]
- Horizontal Branch – helium core fusion (and hydrogen shell fusion) [36-37]
- Asymptotic Giant Branch – helium core exhausted, carbon-oxygen core remains and shell fusion of helium and outer shell burning of hydrogen makes an even larger star… [38-39]

How does a low-mass star die? [pt2_ slides 44-50]

- **What is the process, what is left behind?**
- **What is the size-mass relationship and mass limit on a white dwarf?**

Study Guide – Chapter 13 cont.

13.3. Life as a High-Mass Star

What are the life stages of a high-mass star? [summarized pt3 slide 46]

- **Undergo CNO cycle rather than p-p cycle [pt3_ slides 24-25]**
  - **What are the similarities? What are the differences?**
- Main sequence…
- Supergiant with multiple shells with ever shorter lifetimes of elements remaining in the core as they fuse to eventually form Iron [pt 3, 26-28]
  - Is there a helium flash? Why or why not?
  - Is the process gradual or 'jerky' like for low mass stars?

How do high-mass stars make the elements necessary for life?

- What is helium capture? [pt3 slide 29]
- **What other elements can form within the cores of stars? [pt3, 29-32]**
- **How do heavier elements form? [pt3 slides 40-44]**
- What particle induces the r- and s-processes to form heavier elements?

Study Guide – Chapter 13 cont.

How does a high-mass star die?

- **Why does it matter than Iron collects in the core? [pt 3 slide 32]**
- **What happens to the Iron in the core?**
  - **Degeneracy pressure versus gravity – who wins? [pt3 slides 34-39]**
- **What are the properties of a neutron star? [pt3 slides 16-17]**
  - **Minimum mass?**
  - **Approximate size?**

13.4. Stars in Close Binaries [pt3, slides 48-52]

How are the lives of stars with close companions different?

- Understand that binary systems can interact with each other and 'steal' mass from one another which can affect whether they are main sequence or giant stars
  - Why does this happen? Where is all the mass (gravity) in each star?

Study Guide – Chapter 14

14.1. White Dwarfs

- **What is a white dwarf?**
  - **What stars will form a white dwarf, and what Is it? [ch14 slides 4-8]**
  - **What stops a white dwarf from collapsing to an infinitely small point? [ch14 slides 7-8] – DEGENERACY PRESSURE. What kind? ELECTRON DEGENERACY**
- What can happen to a white dwarf in a close binary system?
  - How does a Nova occur? [ch14_slides 9-10]
  - **What happens if a white dwarf gets larger than 1.4 M_{sun}? [ch14_slides 11-15]**
  - **What causes a type Ia versus a type II supernova? [ch14_slide 13]**
    - **Why are Type Ia supernova useful? [ch16 slides 60-61]**

14.2. Neutron Stars

- **What is a neutron star?**
  - **What stars will form a neutron star? [ch14_slides 4-5]**
  - **What is a neutron star? [ch14 slides 16-19]**
- How were neutron stars discovered? [ch14 slide 20]
  - Most neutron stars are pulsars (act like lighthouses!) [ch14 slides 20-24]

Study Guide – Chapter 14

- What can happen to a neutron star in a close binary system?

14.3. Black Holes: Gravity's Ultimate Victory

- What is a black hole? [ch14, slides 34-38] [ch15, slide 21]
  - Special relativity ~~[ch14, slide 28]~~ [ch15, slide 12]
  - General relativity [ch14, slides 30-33] [ch15, slide 15]
- What would it be like to visit a black hole?
  - What is spaghettification? [ch14, slide 39], [ch15 slide 23]
- Do black holes really exist?
  - *We skipped this, BUT chapter 15 talks about it a little bit…*

14.4. Stars in Close Binaries

- What causes gamma-ray bursts? [ch15_slide 24]
- What happens when black holes merge?
  - Gravity wave detection: LIGO [ch14 slides 25-27]

Study Guide – Chapter 15

15.1. The Milky Way Revealed

- What does our galaxy look like? [ch15, slides 26-29]
  - Can you describe the size, shape and main features of the galaxy? [ch15 slide 28]
  - What kind of galaxy is the Milky Way thought to be? [ch15, slide 29]
  - What do different wavelengths tell us about? [ch15, slide 39]
    - *Which wavelengths tell us about dust?*
    - *Which wavelengths tell us about the presence of atoms? Molecules?*
- **How do stars orbit in our galaxy?**
  - **Disk stars vs. halo stars vs. bulge stars [ch15, slides 30-33]**

15.2. Galactic Recycling

- **How is gas recycled in our galaxy? [ch15 slide 34]**
  - **Most stars give off substantial mass during their lifetime [ch14 slide 5]**
  - **Some stars lose their outer layers (white dwarfs)**
  - **Larger stars explode as supernovae**
    - **Very energetic – but falls back to the disk plane [ch15 slides 34-36]**

Study Guide – Chapter 15

- Where do stars tend to form in our galaxy?
  - How does the spiral remain if stars are moving at different speeds? [ch15 slide 37]
  - **Are older or younger stars found in the spiral arms? [ch15 slide 38]**

15.3. The History of the Milky Way

- What do halo stars tell us about our galaxy's history?
  - Halo population is older with random directions [ch15 slides 33, 40]
- How did our galaxy form? [ch15 slide 40]

15.4. The Galactic Center

- **What is the evidence for a black hole at our galaxy's center?**
  - **Many stars close to the center appear to orbiting something huge [ch15 slide 41]**

Study Guide – Chapter 16

- **Chapter 16: A Universe of Galaxies (Abridged)**

16.1. Islands of Stars

- **What patterns do we find among the properties of galaxy's?**
  - **Different types of galaxies [ch16 slides 43-52]**
  - **Which galaxies are older (redder), or more luminous? Why? [ch16 slide 53]**

16.2. Distances of Galaxies

- **How do we measure the distances to galaxies?**
  - **Parallax method (from previous chapters)**
  - **Standard candles [ch16 slides 55-61]**
    - **Cepheids [ch16 slide 58-59]**
    - **Type Ia supernova [ch16 slides 60-61]**
  - **Hubble's law**
- What is Hubble's law?
  - **What is relationship between red-shift and velocity? [ch16 slides 63-64]**
  - What does Hubble's law tell us about the movement of galaxies? [ch16 slide 64]

Study Guide – Chapter 16

- How do distance measurements tell us the age of the universe?
  - **We can use Hubble's law to tell us how old the Universe is [ch16 slide 66]**
    - *BUT the universe is expanding AND had an inflation period early on…*
    - *These two cancel out in the derived Hubble constant…*
  - **What do we mean by lookback time? [ch16 slide 67]**
    - **Examples – Betelgeuse, Andromeda**

16.3. Galaxy Evolution

- How do we study galaxy evolution?
- Why do galaxies differ?
- How does gas cycle through galaxies?

16.4. The Role of Supermassive Black Holes

- What is the evidence for supermassive black holes at the center of galaxies? *Larger galaxies have larger black holes…*
- Do supermassive black holes regulate galaxy evolution?

Study Guide – Chapter 17

Chapter 17: The Birth of the Universe (Abridged)

17.1. The Big Bang Theory

- *The big bang was the creation of space itself* [ch17 slide 34]

- What were the conditions like in the Early Universe?
  - HOT! ... Laws of physics break down… [ch17 slides 29-30, 33, 37]

- **How did the early universe change with time?**
  - **Planck Era → GUT Era → Electroweak Era → Particle era (10^{-10} s) [ch17 slides 35-39]**
  - **Particle Era – cool enough to form nuclei and excess of ordinary matter [ch17 slide 40]**
  - **Era of Nucleosynthesis – Fusion generates Deuterium, Helium, Lithium [ch17 slide 41, 42] – *Abundances confirm big bang predictions…***
  - **Era of Nuclei – after a few minutes no longer hot enough to sustain fusion [ch17 slide 43]**
  - **Era of atoms ~ 3000 K, 380,000 years. Now cool enough for atoms to form [ch17 slide 44]**
  - **Era of Galaxies (NOW) – there was darkness until the first stars formed [ch17 slides 45-46]**

Study Guide – Chapter 17

17.2. Evidence for the Big Bang

- **How do observations of the cosmic microwave background support the big bang theory?**
  - **What is the cosmic microwave background? [ch17 slides 47-52]**
  - Same in all directions indicates inflation
  - **Scale of variations/patches consistent with 'flat' universe [ch17 slide 52]**
- How do the abundances of the elements support the Big Bang theory?
  - Abundance of helium, deuterium and lithium all match [ch17 slide 42]

17.3. The Big Bang and Inflation

- What key features of the universe are explained with inflation?
- Did inflation really occur?

17.4. Observing the Big Bang for yourself

- Why is the darkness of the night sky evidence for the big bang?
  - **COBE shows the same pattern in different directions – How?**
  - **What is Olber's paradox? [ch17 slide 28]**

Study Guide – Chapter 18

- **Chapter 18: Dark Matter, Dark Energy, and the Fate of the Universe (Abridged)**

- **18.1. Unseen influences in the Cosmos**
- **What do we mean by dark matter and dark energy? [ch18 slide 18]**
  - **Can you describe what dark matter is?**
  - **Can you describe what dark energy is?**
  - **What % of each are needed to reach the critical density?**
  - **What % of each are needed to explain the observed density?**

- **18.2. Evidence for Dark Matter**
- **What is the evidence for dark matter in galaxies? [ch18, slides 19-26]**
- **What is the evidence for dark matter in clusters of galaxies?**
  - **What is the Mass-to-light ratio? [Ch18 slide 27]**
  - **Evidence from gravitational lensing [Ch18, slides 28-29]**
  - **Evidence from X-rays of gases between clusters [ch18, slides 30-32]**

Study Guide – Chapter 18

- Does dark matter really exist?
  - Ordinary matter alone cannot explain many features of the Universe… [ch18 slides 36, 41], as well as section 18.2
- **What might dark matter be made of?**
  - **Probably not MACHOs [ch18 slide 32]**
  - **Probably WIMPS [ch18 slide 33]**

18.3. Structure Formation

- What is the role of dark matter in galaxy formation? [ch18 slide 36]
- What are the largest structures in the universe? [ch18 slide 35]

- 18.4. Dark Energy and the Fate of the Universe [ch18 slides 37-41]
- **What is the evidence for an accelerating expansion?**
  - **Observations of type Ia supernova & red-shifts [ch18 slide 39]**
- **Why is flat geometry evidence for dark energy? [ch18 slides 40-41]**
  - **Normal matter ~ 5%, Dark matter ~ 27 % … *'68% missing' but $E=mc^2$***
- What is the fate of the universe? [ch18 slides 37-41]

Study Guide – Chapter 18

Chapter 19: Life in the Universe (Abridged)

19.1. Life on Earth

- **When did life arise on Earth? [ch19 slides 19-38]**
  - **Can you explain the evidence and time of the following:**
    - **Earliest evidence for life? [ch19 slide 21]**
    - **Earliest fossils (and stromatolites)? [ch19 slide 22]**
    - **Cells with a nucleus**
    - **The rise in oxygen – what does this allow for? How? Ozone! [slide 37, 46]**
    - **The Cambrian explosion**
    - **The extinction of the dinosaurs (K-T boundary)**

- How did life arise on Earth?
  - The path to RNA/DNA/protein world is unclear [ch19 slides 22-29]
  - **LUCA and extremophiles [ch19 slides 28, 33]**
  - **Potential contributions from: [ch19 slides 30-32]**
    - **Atmosphere**
    - **Hydrothermal vents**
    - **Extraterrestrial delivery**

Study Guide – Chapter 18

- What are the necessities of Life? [ch19 slide 34, 39, 48]
  - Liquid water! … also energy, and stable environment…

19.2. Life in the Solar System

- Could there be life on Mars? [ch19 slides 40-42]
- Could there be life elsewhere in the Solar System? [ch19 43-45]

19.3. Life Around Other Stars [ch19 slides 46-48]

- What are the requirements for surface life?
- What kinds of extrasolar worlds might be habitable?
- How could we detect life on extrasolar planets?

Study Guide – Chapter 18

19.4. The Search for Extraterrestrial Intelligence [ch19 slides 56-59]

- **How many civilizations are out there? – How does SETI work?**

19.5. Interstellar Travel and It's Implications for Civilization [ch19 slides 50-60]

- **How difficult is interstellar travel? Where are the aliens?**

Good Luck!