Ay 10 - Fall 2006

Review Outline for Final Exam[1]

1. Lecture 1
   (a) Astronomy vs. astrology
   (b) Occam's razor: what is it?
   (c) Retrograde motion (qualitatively)
   (d) Kepler's laws (qualitatively)
   (e) Newton's laws (especially gravity, you should know Newton's law of gravity quantitatively)
2. Lecture 2
   (a) Be comfortable using powers of ten and scientific notation
   (b) Be comfortable with simple unit conversions
   (c) Be comfortable estimating quantities (e.g. how much water have you drunk in your life)
   (d) Parallax: both qualitatively and quantitatively
3. Lecture 3
   (a) What is a spectrum? Be ready to interpret spectra
   (b) Understand properties of light: λ, ν, E (the energy of individual photons), the speed of light, c (Question 5 on problem set 2 would be a great one to go over again)
      i. How are λ and ν related?
      ii. How are E and ν related?
   (c) Be familiar with the electromagnetic spectrum (e.g. do radio waves have longer wavelengths than visible light? Do red visible photons have more energy than blue visible photons? etc.); no need to memorize specific wavelengths
4. Lecture 4
   (a) Doppler effect: qualitatively and quantitatively (Problem set 2, questions 2 and 4 are good to review)
   (b) Blackbody radiation:
      i. What is blackbody radiation?
      ii. Be able to plot a blackbody spectrum
      iii. Know Wien's law
      iv. Don't worry about the Stefan-Boltzmann law just yet, we'll get to it later

[1]Thanks to Onsi Fakhouri and Anna Treaster for putting this together.

(c) Emission and absorption lines: look at problem set 3, question 1; understand how energy levels work
   i. Understand how emission lines are formed
   ii. Understand how absorption lines are formed

5. Lecture 5
   (a) More on emission and absorption lines
   (b) Luminosity, flux, and the inverse square law for light
   (c) Telescopes:
      i. Collecting power (a.k.a. collecting area) qualitatively and quantitatively
      ii. Chromatic aberration (qualitatively)

6. Lecture 6
   (a) Diffraction limit (qualitatively and quantitatively)
   (b) Atmospheric blurring
   (c) Adaptive optics
   (d) Benefits of telescopes in space

7. Lecture 7
   (a) Detectors (qualitatively)
   (b) Radio telescopes
   (c) Interferometry (qualitatively)

8. Lecture 8
   (a) Phases of the Moon
      i. Orbit of Moon around Earth
      ii. Sidereal month
      iii. Synodic month
      iv. Same face of Moon always faces Earth
   (b) Tides on Earth created by Moon and Sun
   (c) Eclipses of the Moon and Sun
      i. Total versus partial eclipses
      ii. Inclination of Moon's orbit compared to Earth's orbit (do we see an eclipse every time the Moon orbits Earth?)

9. Lecture 9
   (a) Earth's atmosphere
      i. Scattering: blue light scattered more than red
         A. Sky blue

        B. Sunsets red
    ii. Refraction
  (b) Earth's elliptical orbit
  (c) Seasons
    i. Winter solstice and summer solstice
    ii. Spring equinox and autumnal equinox
    iii. Why some seasons are warmer and other colder based on the tilt of the Earth

10. Lecture 10
    (a) Greenhouse effect (how it works, qualitatively)
    (b) Earth's magnetic field, Van Allen belts, and aurorae
    (c) Kepler's three laws (qualitatively and quantitatively), Newton's version of Kepler's third law (see problem set questions too!)
    (d) Mercury
        i. Precession of Mercury's orbit
    (e) Venus
        i. Evening/Morning Star
        ii. Runaway greenhouse effect
    (f) Mars
        i. Why it's red
        ii. Dust storms, windy

11. Lecture 11
    (a) Asteroids
        i. vs. meteor, meteorite, meteoroid (see problem set)
    (b) Comets
        i. Two tails
    (c) Meteor showers
    (d) Gas giants: Jupiter
        i. Most massive
        ii. Massive storms on surface, e.g. Red Spot
        iii. Io: most active object in solar system, why does it have volcanoes?
        iv. Europa: possible ocean
    (e) Gas giants: Saturn
        i. What are the rings made of?
    (f) Gas giants: Uranus
        i. Large tilt (97 degree tilt) = long seasons
        ii. What are shepherd moons?

(g) Gas giants: Neptune
(h) Kuiper-belt, Oort cloud
    i. Understand the differences between the two
    ii. Understand what the two are made up of
    iii. Which is the source of short-period comets? Long-period comets?

12. Lecture 12
    (a) Condensation theory of solar system formation
        i. Understand how it works, step by step
    (b) Extrasolar planets/solar systems
    (c) Different techniques for finding extrasolar planets
        i. Astrometric technique
        ii. Doppler (radial velocity) technique
            A. Have found lots of nearby extrasolar planets
            B. What are hot Jupiters?
            C. Inclination gives us a lower limit on the mass
        iii. Transit techniques
            A. Understand, quantitatively, how to calculate the fraction of starlight that is blocked when the planet passes in front of the star
        iv. Other techniques

13. Lecture 13
    (a) The Sun
        i. What is the photosphere?
        ii. What is the corona?
        iii. What are Sunspots and why are they dark?
        iv. Hot core gives us blackbody continuum, outer layer blocks certain wavelengths
    (b) Spectral classification (OBAFGKMLT)
    (c) Stephan-Boltzmann law (quantitatively)
    (d) Inverse square law (quantitatively)
    (e) HR Diagram
        i. Understand what it is!
        ii. Be able to plot one
        iii. Be able to label all the important regions
    (f) Masses of stars
        i. 3 techniques for getting the mass of binary star systems
            A. Doppler measurement of shifts in the spectra
            B. Visually measuring the orbit
            C. Eclipsing binaries (similar to transit method for extrasolar planets)

(g) Mass-Luminosity relation: $L \propto M^4$

(h) Stellar lifetime relation: lifetime $\propto \frac{\text{energy available}}{\text{stellar luminosity}} \propto \frac{M}{L} \propto \frac{M}{M^4} \propto M^{-3}$

(i) Star clusters

   i. Open vs. Globular

   ii. How are they related to stellar ages?

   iii. How can we tell the age of a cluster (see problem set)

14. Lecture 14

   (a) Interstellar Matter

      i. Absorption vs. scattering/reddening

      ii. Emission vs. reflection nebulae

   (b) Star formation: from cloud collapse to protostar

   (c) Stellar evolution (be sure to know how the different phases work, and know how to plot them on an HR diagram!)

      i. Pre-Main Sequence: powered by gravitational energy, contracting core heats up

      ii. Birth of a star

         A. Fusion begins

         B. Hydrostatic equilibrium: gravity vs. pressure

      iii. Main Sequence

         A. Core is hot, can fuse

         B. Energy released when converting hydrogen into helium is $0.007 m_H c^2$ where m_H is the total mass of hydrogen converted into helium

         C. Proton-proton chain

         D. $E = mc^2$

         E. Photons generated by p-p chain take a long time to get out of the Sun's core

         F. Lifetime on Main Sequence (Sun is 10 billion years)

      iv. Death of stars, low mass case ($M < 8 M_\odot$)

         A. Red giant phase

         B. Planetary Nebula

         C. White Dwarf

15. Lecture 15

   (a) Stellar evolution continued (be sure to know how the different phases work, and know how to plot them on an HR diagram!)

      i. A closer look at White Dwarfs:

         A. Electron degeneracy pressure fights gravity

         B. Stored up heat is slowly radiated (no fusion)

         C. Chandrasekhar mass (equal to $1.4 M_\odot$)

      ii. Death of High Mass stars ($M > 8 M_\odot$)

            A. Blue and red supergiants
            B. Iron core is reached, fusion cannot continue
   (b) Mass exchange in binary systems
       i. Roche lobe
   (c) Novae

16. Lecture 16
   (a) Novae
   (b) Supernovae
       i. Type I vs. Type II
            A. What are the differences?
            B. In what regions of galaxies do we see them? Why?
            C. Understand qualitatively what happens during a type I or type II supernova
            D. Role of neutrinos in type II supernovae
            E. Create heavy elements and distribute them
            F. Recycles stellar material
       ii. Supernova remnant (e.g. crab nebula)
       iii. Supernova rate in the Milky Way, why don't we see this many?

17. Lecture 17
   (a) Type Ib, type Ic supernovae
   (b) GRBs
       i. Potential GRB suspects
       ii. Flavors of GRB bursts
   (c) Brown Dwarfs

18. Lecture 18
   (a) Neutron star birth
       i. Neutron degeneracy pressure
       ii. Role in supernovae
   (b) Neutron star size, mass
   (c) Pulsars
       i. Why neutron stars?
       ii. Why would a neutron star turn off and on?
       iii. Why aren't all neutron stars pulsars?
       iv. Millisecond pulsars are spun up by matter falling in from a companion
   (d) Neutron stars in binaries: bursts of X-ray radiation
   (e) Testing General Relativity
       i. Precession of Mercury's orbit

    ii. Bending of starlight near the Sun
    iii. Gravitational redshift of light
    iv. Pulsar binaries (periods decay because of gravitational waves)

19. Lecture 19
    (a) Formation of Black Holes
    (b) Schwarzschild radius
        i. Event horizon is this far from singularity
    (c) Singularity at the center
    (d) Photons and black holes:
        i. Gravitational redshift of photons
        ii. Photon sphere
    (e) Properties of black holes:
        i. Not cosmic vacuums
        ii. Very simple objects ("no hair theorem")
    (f) Effects around black holes
        i. Spaghettification
        ii. Time slows as gravitational field intensifies
    (g) Accretion disks around black holes
    (h) Spinning Black Holes
    (i) Evaporating Black Holes
    (j) Wormholes

20. Lecture 20
    (a) Spiral galaxy structure: bulge, halo, disk, nucleus
        i. spiral arms rotate but don't wind up or unwind
        ii. lots of gas and dust so lots of new star formation
    (b) measuring distances using variable stars: Cepheids, RR Lyrae stars
        i. period/luminosity relation for Cepheids
    (c) stars, like the Sun, orbit around the center of a spiral galaxy

21. Lecture 21
    (a) rotational velocity curves
        i. know how to get mass profile knowing rotation curve or vice versa
        ii. rotation of galaxies versus solar system
    (b) dark matter
        i. needed for rotation curves to make sense

        ii. candidates for dark matter are MACHOs (black holes, white dwarfs, red dwarfs, brown dwarfs) and WIMPs (weird subatomic particles)
   (c) Elliptical Galaxies
        i. No gas and dust so no new star formation
        ii. No spiral arms, no disk
   (d) Irregular Galaxies
        i. Examples are the small and large magellanic clouds, the nearest galaxies to the Milky Way

22. Lecture 22
   (a) Galaxy clusters
        i. small groups of around a dozen galaxies to clusters with over 10,000 galaxies
        ii. Superclusters are clusters of clusters
   (b) gravitational lensing
        i. light bent by lots of mass, like a galaxy cluster, to make an image brighter or make multiple images of one object
        ii. used as a way to find dark matter clumps
   (c) Hubble's Law
        i. recession velocity increases with distance
        ii. Slope is Hubble's constant, H_0
        iii. $v = H_0 * d$
   (d) Redshift: $z = \frac{\lambda_{\text{obs}} - \lambda_{\text{em}}}{\lambda_{\text{em}}}$ and for close objects $z \approx \frac{v}{c}$
   (e) lookback time increases as redshift increases
   (f) ways to measure distance
        i. variable stars liked Cepheids
        ii. supernova type Ia
        iii. Tully-Fisher Relation

23. Lecture 23
   (a) AGN (active galactic nuclei): massive black holes produce huge luminosities
        i. Most famous type is quasars
        ii. Black hole creates extremely bright jets of radiation
   (b) black hole at the center of the Milky Way: big, but not as big as an AGN black hole

24. Lecture 24
   (a) large scale structure of the universe seen to about 300 Mpc
   (b) Cosmological Principle: universe is homogeneous (even) and isotropic (has no preferred direction)
   (c) Cosmological redshift because the space of the universe is expanding

(d) age of the universe is roughly $\frac{1}{H_0}$ = 13 to 14 billion years = 13 to 14 Gyr

(e) Olber's Paradox: universe can't be infinite and have existed forever; now we know universe had a beginning point

(f) Big Bang Theory

i. Universe started at a single point and expanded outward

ii. Scale factor R increases with time

(g) Critical density, ρ_{crit}, is density needed to make the universe closed

i. $\Omega = \frac{\rho}{\rho_{\text{crit}}}$ is the density parameter (can define for matter, dark energy, or anything else in the universe)

ii. Fate of the universe (based on the density of matter)

A. $\Omega_m > 1$ universe collapses back on itself (closed universe)

B. $\Omega_m = 1$ universe expands forever but expansion rate slows to 0 as time goes to infinity (flat universe)

C. $\Omega_m < 1$ universe expands forever and slows down slightly but never gets to an expansion rate of 0 at a time of infinity (open universe)

D. $\Omega_m = 0$ universe expands forever and never slows down (empty universe)

(h) Shape of the Universe

i. Closed

ii. Open

iii. Flat

25. Lecture 25

(a) supernova type Ia as standard candles for distance measurements

(b) Universe's expansion is accelerating!

(c) dark energy

i. anti-gravity force powering the expansion of the universe

ii. we don't know what it is

iii. will cause the universe to expand forever at an ever-increasing rate

(d) CMB (cosmic microwave background)

i. Radiation from about 300,000 years after the Big Bang

ii. At a temperature of about 3 K

iii. Has tiny fluctuations that are uniform across the whole sky

iv. Created when photons stopped interacting with newly formed hydrogen atoms

(e) Our Universe

i. 4% normal matter (stuff we can see)

A. 0.5% stars and visible gas

B. 3.5% hot interstellar gas

ii. 23% dark matter

iii. 73% dark energy

iv. $\Omega_{\text{tot}} = 1$ so universe is flat

26. Lecture 26
    (a) Stages of the Universe
        i. Big Bang
        ii. Planck Era (all forces unified)
        iii. GUT Era (gravity becomes a unique force, rest of the forces are unified)
        iv. Particle Era (matter and antimatter particles)
        v. Nucleosynthesis (protons and neutrons formed)
        vi. Era of Nuclei (hydrogen and helium nuclei float around in a hot plasma)
        vii. CMB released at end of the era of nuclei
    (b) Big Bang's successes:
        i. Predicts CMB perfectly
        ii. Predicts abundances of hydrogen, helium, deuterium, etc.
    (c) Theory of Inflation
        i. Says universe expanded enormously in a tiny fraction of a second right after the Big Bang
        ii. Explains why the universe is flat (i.e. solves the Flatness Problem)
        iii. Explains why the universe is homogeneous and isotropic (i.e. solves the Horizon Problem)
27. Lecture 27
    (a) Possible signs of life:
        i. Liquid water on Mars or moons in our solar system
        ii. Simple amino acids in meteorites
    (b) Drake Equation:
        i. $N = R_* * f_p * n_e * f_l * f_i * f_c * L$
        ii. Tells how many communicating civilizations we expect to find in our Galaxy
        iii. Some parameters are scientific (especially the first few), but the variables at the end are adaptable to personal belief
    (c) Space missions have been sent out to try to communicate with other life (Voyager I and II)
    (d) SETI: trying to communicate with radio waves