Final Exam - Tuesday, May 4
9:00am to 11:00am

- Closed book
- Will cover all of the lectures, as evenly as possible
- If a topic is in the book, but was not covered in class, it will not be on the exam!
- **Exam Format - similar to midterms (mix of questions)**
- Equations, constants will all be given
- Standard calculators allowed **(but not provided)**
- Cell phones, PDAs, computers not allowed

One last chance to complete NL#2

The forecast for tonight is looking good for NL#2.

If it's reasonably clear tonight, there will be one last opportunity to do NL#2.

Due date for NL#2 is **extended to 5:00pm on Friday** (hand in using the Homework Box upstairs).

The "Big Stuff"

AS102 Review

Lecture #1

- Astronomy as a science (information comes mostly from light and astronomy is a "passive" science)
- Big view of the universe: solar system vs. stars in general vs. galaxies

Lecture #2

- Our place in the universe
- The universe as a time machine
- Motion in the universe (rotation and revolution of the earth, revolution of the sun, motion of galaxies in the Local Group, Hubble's Law)
- What can be seen in the sky without a telescope?
- What is a constellation and why do the constellations that you see change with the seasons and with your latitude on earth?

Lecture #3

- Cause of the seasons (why distance from the sun doesn't matter)
- Cause of the moon's phases (why it can't be the shadow of the earth)
- Concept of "angular sizes" of cosmic objects (related to eclipses)

Lecture #4

- Motions of the planets with respect to the "fixed" stars
- Cause of retrograde motion
- Stellar parallax as proof that the earth orbits the sun
- Ancient Observatories
- Ancient Greek Rationale for a stationary earth
- Ptolemy's geocentric model of the solar system
- Copernicus' heliocentric model of the solar system
- Tycho Brahe's observations of the sky

Lecture #5

- Kepler's laws of planetary motion
- Galileo's observations that discredited the Aristotelian view of the heavens
- Difference between speed and velocity
- Newton's laws of motion
- Newton's explanation of orbital motion via the action of a force
- Use of Newton's laws to measure the masses of cosmic objects via orbital motion

Lecture #6

- Light
- Wave vs. particle properties of light
- Brightness vs. luminosity
- Photoelectric effect
- Energy of a photon
- Electromagnetic spectrum

Lecture #7

- Emission, absorption and continuous spectra
- Spectra as the “fingerprints” of atoms (due to changes in energy levels)
- Black Body spectrum (what objects give you a BB spectrum and how can you use it to measure temperature)
- Doppler shift (motion towards/away from you)

Lecture #8

- Special Relativity (What’s “special” about it? What are the two basic postulates?)
- Motion, simultaneity, passage of time, measurements of length are all relative
- Time dilation and length contraction
- Boost factor (tells you the difference between what the “passenger” and “bystander” see)
- Space-time interval (what all observers can agree on)
- Mass increases with speed (practical considerations for space travel at speeds near c)

Lecture #9

- General relativity
- Equivalence principle
- Consequence of equivalence principle for a beam of light
- Proof of reality of time dilation (1971 Naval Observatory experiment)
- Gravitational redshift
- In general, space is curved not flat
- Matter tells space how to curve
- Curvature tells things how to move

Lecture #10

- Einstein’s explanation for planetary orbits (elimination of “spooky” action at a distance)
- Proofs of GR as the most general theory of gravity (precession of the perihelion of Mercury, gravitational lensing)
- Black hole basics: escape speed, Schwarzschild radius
- How close can you get to a black hole and still escape?
- What would a trip into a black hole be like?

Lecture #11

- Observational evidence for black holes
- Importance of hot gas (x-rays) and fast rate of light “flickering”
- Supermassive vs. stellar mass black holes
- Basic properties of stars
- Observed ranges of luminosity, temperature, radius, and mass of stars

Lecture #12

- Stellar spectra (OBAFGKM)
- Spectral sequence is a temperature sequence (not chemical composition)
- H-R diagram for stars
- Proof that the sun cannot be solid
- Gravitational equilibrium in the sun
- Sun (and all other main sequence stars) get their power from fusion of H, producing He
- Strong force and the conversion of mass into light

Lecture #13

- Stellar mass determines the main sequence lifetime (gas guzzlers vs. econoboxes)
- How to estimate the ages of stars using H-R diagrams of star clusters
- Interstellar medium (ISM)
- Stars form in very cold, dense regions of gas (molecular cloud cores)
- To form a star from a gas cloud, gravity has to “win” over pressure

Lecture #14

- Protostars (in the process of contracting and heating up)
- Luminosity of protostars comes from conversion of gravitational potential energy
- Disks naturally form around protostars because of conservation of angular momentum
- Eventually should have planet formation in the disks (planet formation should be a generic part of star formation)

Lecture #15

- Stellar evolution
- Build up of He ash in the core causes stars to leave the main sequence
- Cycle of contraction of the core and expansion of the envelope, fusing heavier and heavier nuclei in the core
- Low mass stars end their lives as a carbon-oxygen white dwarf and a planetary nebula

Lecture #16

- High mass stars end their lives as either neutron stars or black holes after undergoing a supernova
- Supernova of high mass star triggered by build up of iron in the core
- White dwarf novae and supernovae must occur in binary systems

Lecture #17

- Pulsars (rapidly-rotating neutron stars left over after a high-mass star supernova)
- Hypernova gives rise to a few-second burst of gamma rays and leaves behind a black hole (progenitor star would have had a main sequence mass > 40 M_{sun})
- Introduction to the Milky Way
- Face-on vs. edge-on perspectives of a spiral galaxy
- Halo, bulge, disk are the main components

Lecture #18

- Orbital motions of stars in the Milky Way (disk vs. halo)
- Mass of Milky Way from rotation speeds of stars (leads to “dark matter”)
- Distribution of stars, gas, and dust in the Milky Way
- Most cold gas is in the arms
- There are not vastly more stars in the arms than in the rest of the disk
- Hot, ionized gas traces the spiral arms (near the young stars that “light up” the arms)
- Large clouds of gas collapsing in isolation most likely give rise to a spiral galaxy
- Basic galaxy types (elliptical, spiral, irregular, lenticular/S0) and their physical properties

Lecture #19

- Hubble “tuning fork” diagram is not an evolutionary sequence of galaxies
- Groups and clusters of galaxies
- Distances to galaxies (Cepheid variable stars, Tully-Fisher relationship, white dwarf supernovae)
- Hubble’s law revisited
- Why Hubble’s law does not say that we are at the center of the universe

Lecture #20

- Cosmological principle and its implications
- Physical cosmology (universe is all that is physical, including space and time)
- Using Hubble law to estimate the age of the universe
- Cosmological redshift is technically not a Doppler shift (photons lose energy as they travel to us)
- Energy density in light drops faster than energy density in mass due to redshift of the photons
- Big Bang predictions
- Olbers’ paradox (darkness at night)

Lecture #21

- Lookback times (universe as a time machine)
- Galaxies “here and now” vs. “there and then”
- Direct evidence of galaxy evolution (test of big bang theory)
- Importance of collisions and mergers for establishing galaxy morphology
- Active galaxies (including quasars): light from material nearby central supermassive black hole, common in the past but rare today (another case for galaxy evolution)

Lecture #22

- Theoretical fates for the universe
- Gravity as “brakes” on the expansion
- Evidence for dark matter from galaxies and clusters of galaxies
- WIMPs as the favorite theory of dark matter
- White dwarf supernovae in distant galaxies as evidence of dark energy and an acceleration of the expansion of the universe

Lecture #23

- Fossil photons from the big bang (CMBR)
- CMBR is near-perfect black body and best proof of isotropy of the universe
- Pattern to the temperature fluctuations in the CMBR give further evidence of dark energy
- Creation of mass (building blocks of atoms) from light in early universe
- Fusion in the early universe to create helium and trace amounts of lithium and beryllium
- Unanswered questions related to the big bang
- Is the big bang a “good” theory?