ASTR 105
Intro Astronomy: The Solar System

Today: FINAL REVIEW

This Thursday 12/03: Major Group Project #2 [LECT 13-22]

FINAL EXAM on Thursday, 12/17, 8:00am-10:45am
1. Our Place in the Universe

- Types of objects in the universe
- Solar system scale
- Measuring distance with light
- Lookback time
2. Discovering the Universe (Celestial Motions)
Celestial Sphere

- Zenith, Horizon, Meridian
- Altitude, direction
- Latitude (and Longitude) on Earth as told by the stars
**Motions: Actual vs. Apparent**

- **Daily motion**
  - *Apparent*: stars rise in east, set in west
  - *Actual*: Earth spins from west to east

- **Annual motion**
  - *Apparent*: Sun appears in different constellations
  - *Actual*: Earth orbits around the Sun ever 365 days
The Reason for the Seasons

CLOSER ≠ MORE
How do we mark the progression of the seasons?

- We define four special points in our orbit (dates):
  - Summer solstice
    - Northern hemisphere tilted towards the Sun
  - Winter solstice
    - Northern hemisphere tilted away from the Sun
  - Spring (vernal) equinox
    - North and South: equal distance from the Sun
  - Fall (autumnal) equinox
Although the Moon is always $\frac{1}{2}$ lit by the Sun, we see different amounts of the lit portion from Earth depending on where the Moon is located in its orbit.
Eclipses

The pond surface represents the ecliptic plane (the plane of Earth's orbit around the Sun).
3. The Science of Astronomy
Geocentric vs Heliocentric

Earth-Centered (Geocentric)

- Retrograde motion
- Parallax
- Nature of Science
- Astrology

Sun-Centered (Heliocentric)

KEPLER'S 3 LAWS OF PLANETARY MOTION
4. Making Sense of the Universe
Sir Isaac Newton

**Newton's 3 laws**
- Speed vs velocity vs acceleration
- Fire extinguishers and rockets

**Universal law of gravitation** (the inverse square law of gravity)
- Acceleration of gravity
- Cabbage vs ball (hammers vs feathers), Darth V. on a ladder
- Tides
Orbits

- Circular velocity
- Escape velocity

Newton's Version of Kepler's 3rd Law

$$P^2 = \left\{ \frac{4\pi^2}{GM} \right\} a^3$$

What M matters?
7. The Planets

Terrestrial Planets

Mercury, Venus, Earth, Mars

Jovian Planets

Jupiter, Saturn, Uranus, Neptune

Dwarf Planets

Ceres, Pluto, Haumea, Makemake, Eris
1. Large bodies in the solar system have orderly motions
2. Planets fall into two main categories
3. Swarms of asteroids and comets populate the rest of the solar system
4. Several notable exceptions to these general trends stand out
8. **Nebular Theory of Solar System Formation**

- **Collapse**
- **Condensation**
  - Frost line
- **Accretion**
- **Gas capture**
  - (Jovians)
- **Solar wind clearing**
- **Heavy bombardment**
Processes that HEAT planets:

- Accretion
- Differentiation
- Radioactivity

Processes that COOL planets:

- Convection
- Conduction
- Radiation

1. Convection
   Hot rock rises and cooler rock falls in a mantle convection cell.

2. Conduction
   After convection brings heat to the base of the lithosphere, conduction carries heat through the rigid lithosphere to the surface.

3. Radiation
   At the surface, energy is radiated into space.
4 Processes that Shape Surfaces

- **Volcanism**
  - Eruption of molten rock onto surface

- **Impact cratering**
  - Impacts by asteroids or comets

- **Tectonics**
  - Disruption of a planet's surface by internal stresses

- **Erosion**
  - Surface changes made by wind, water, or ice
Planets Have Three Basic 'Formation Properties' or 'Fundamental Properties'

- Size (mass & radius)
- Distance from Sun
- Rotation rate
5. Light and Matter

- Waves vs Particles
- Wavelength vs Frequency vs Energy
  - Speed of light
Four Ways in Which Light can Interact with Matter

1. **Emission** - matter releases energy as light
2. **Absorption** - matter takes energy from light
3. **Transmission** - matter allows light to pass through it
4. **Reflection** - matter repels light in another direction
Kirchhoff's Laws

Wien's Law

Graph showing relative intensity per square meter of surface versus wavelength (nm). Curves for 15,000 K star, the Sun (5,800 K), 3,000 K star, and 310 K human are presented, with ultraviolet and infrared labels.
Double Hump Spectrum for Planets

Visible Sunlight IN

Absorbed Sunlight

IR Thermal Emission OUT

Energy IN

Energy OUT
10. Planetary Atmospheres
Earth's Atmosphere

**Exosphere**
heated by solar UV and X rays; fast-moving gas molecules can escape to space

**Thermosphere**
X rays heat and ionize gases

**Stratosphere**
heated by UV light; no convection

**Troposphere**
greenhouse gases trap infrared radiation from the ground; convection important
Atmospheric Sources

- Outgassing
- Evaporation/sublimation
- Bombardment (by micrometeorites, solar wind, and/or high-energy photons)

Atmospheric Losses

- Thermal escape
- Solar wind stripping
- Condensation
- Chemical reactions with surface materials
- Large impacts can blast atmospheric gases into space.
11. Jovian Planet Systems
Outsides...

Jupiter
Distance from Sun = 5.20 AU
Mass = 318 $M_{\text{Earth}}$
Density = 1.33 g/cm$^3$
Composition: mostly H, He

Saturn
Distance from Sun = 9.54 AU
Mass = 95 $M_{\text{Earth}}$
Density = 0.71 g/cm$^3$
Composition: mostly H, He

Uranus
Distance from Sun = 19.2 AU
Mass = 14 $M_{\text{Earth}}$
Density = 1.24 g/cm$^3$
Composition: H compounds, rock, H and He

Neptune
Distance from Sun = 30.1 AU
Mass = 17 $M_{\text{Earth}}$
Density = 1.67 g/cm$^3$
Composition: H compounds, rock, H and He

And Insides...

Jupiter
visible clouds
metallic hydrogen
liquid hydrogen
gaseous hydrogen
core of rock, metals, and hydrogen compounds

Saturn
visible clouds
gaseous hydrogen
core: rock and metals; water, methane, and ammonia

Uranus

Neptune

Jovian Planets - So Many Moons!

Small moons  Large moons

Jovian moons behave differently! (than terrestrial worlds)

• **Tidal Heating**
  - Orbital Resonances
  - Tidal Friction

• **Differing composition**
  - Ices instead of rocks
Astrometric Technique

Doppler Technique

Transit Technique
Characteristics of Extrasolar Planets

- Selection effects vs actual distributions
- High mass planets close in with high eccentricities
  - Orbital resonances
  - Planetary migration
Poll Question

What was your favorite topic in this course?

A. Celestial Motions (celestial sphere, seasons, lunar phases, eclipses)
B. Astronomical Physics (Kepler's laws, Newton's laws, gravity, orbits)
C. Solar System Formation
D. Terrestrial Planets (geology/ atmospheres)
E. Jovian Planets & their moons OR Extrasolar planets
“Look again at that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every 'superstar,' every 'supreme leader,' every saint and sinner in the history of our species lived there-on a mote of dust suspended in a sunbeam. ... Our planet is a lonely speck in the great enveloping cosmic dark. ... There is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world. To me, it underscores our responsibility to deal more kindly with one another, and to preserve and cherish the pale blue dot, the only home we've ever known.”