Final Exam: Fri 4 May 3:00-5:00 p.m. In This Room!

Exams will be multiple-choice questions. Please remember to bring a pencil, calculator and a scantron (20052)

The exam will cover one terrestrial planet, **Mars (Lecture 10)**, one Jovian Planet, **Saturn (Lecture 12)** & **Lectures 20 - 22**

Lecture 10 Mars: The Red Planet That Tried To Eat Tom Cruise

1) <u>Orbit, Rotation, & Basic Properties</u>

elliptical orbit
Martian day is 24.6hrs
rotational axis is tilted like Earth's → Mars has Seasons!
~ ½ the Earth's diameter
~ 1/10 the Earth's mass
Mars and Earth have similar density (but Mars' is somewhat lower).
Mars has a thin atmosphere.
why is Mars fainter than Venus?
why is the surface red?

2). <u>Surface of Mars</u>

- Volcanoes (Olympus Mons is the biggest in the solar system)
- "splosh" craters common
- Mariner Valley (not a real canyon – i.e., not formed by water).
- Tharsis bulge opposite Hellas Basin
- no crustal plates. Crust is one piece. No continents or continental drift.
- Mars' surface divided into two halves:
    - Northern Plain: flat, low elevation, few craters
    - Southern Highlands: rugged, high elevation, lots of craters
- Running water on Mars? What is the evidence?
  (Gullies at crater edges, flash-flood flows, ancient rivers)
- Where did the water go???
- would water boil at 10 C on the surface of Mars? Can you make a good cup of tea?
- Polar Ice Caps
    - composition; how they change with the seasons?

3) <u>The Atmosphere of Mars</u>

- composition (mostly CO_2, like Venus)
- Mass (thin atmosphere, not much protection from meteorites)
- temperature and density (cold and thin)

4) <u>A Run-away Greenhouse Effect in **Reverse**!</u>

- be able to describe this process (i.e., green-house gases **taken <u>out</u>** of the atmosphere)

5). Life on Mars

- The three experiments of Viking I & II: what were they?
- what was so important about the sterilized sample from Earth
- Were the Viking experiments conclusive one way or the other?

6) The Martian Moons

- composition (do they have the same composition as the planet Mars?)
- where are they thought to have arisen? How did they wind up going around Mars?
- They are very small and heavily cratered.

Lecture 12 Saturn

1) Be Familiar With Orbit, Rotation, & Basic Properties of Saturn

- Saturn is the 2nd largest planet in the Solar System.
- Saturn is 10x larger than the Earth.
- Saturn is more "squashed" in shape then Jupiter, implying that is more gaseous then Jupiter, and less rocky than the Earth.
- Saturn is 100x more massive as the Earth.
- Saturn's density is less than water – 0.7 g/cm^3. **It would float in water!**
- Saturn's magnetic field is 1,000 times stronger than Earth's.
- Saturn has **lots** of moons (31),. Most are very small.
- Saturn is famous for its beautiful **rings.**
- Saturn's moons exhibit some odd orbital motion – name 3 examples.

2) Saturn's Atmosphere

- composition: very similar to Jupiter's with one exception: *Saturn has much less Helium in its atmosphere than Jupiter does*.
  -- the helium has condensed into droplets in Saturn's outer atmosphere and "**rained"** down to lower levels.
- Saturn's atmosphere also shows alternating colored bands of clouds, but the colors are much more subdued. Less colorful.
- hurricane ("cyclone") like storms are rarely seen in Saturn's atmosphere, and they are short-lived.
  → Nothing like Jupiter's Red Spot.

3) Saturn's Internal Structure

- Like Jupiter, we know very little of Saturn's interior. But it is probably: (1) rocky core, (2) metallic hydrogen mantle, (3) outer layer of molecular hydrogen, and (4) the atmosphere we see.

4) Saturn's Magnetosphere

- Saturn also has a strong magnetic field due to its rapid rotation and metallic hydrogen core: ~1,000 times stronger than Earth's
- Saturn also has Aurora: Northern & Southern Lights!

5) Saturn's Rings

- Saturn is surrounded by a system of very bright rings, visible from Earth.
- since Saturn's axis is tilted (26.7 degrees), the rings look different during Saturn's 29.4-year orbit around the Sun.
- the rings are extremely thin – a few tens of meters in places.
- the rings are composed of large numbers of bits of debris: sizes range from sand-grain to tens of meters. On average: snowball sized.
- the debris is coated in water ice, which explains why they are so bright.
- the rings are actually hundreds of small ring-lets.
- The outer-most ring (F-ring) appears "braided", and is kept in place by two small "Shepherd moons".

- The rings exist within a zone called the "Roche Limit".
  - →Any moon, comet, or asteroid straying inside the Roche Limit is torn apart into rubble by Saturn's gravitational field.

Roche limit = 2.4 x planets radius – using what assumptions?

- rings probably relatively new -small icy moon fell within Roche Limit within past 100-million years.

The Universe of Galaxies (Lecture 20)

a. How do we measure distances to Galaxies?

- RR Lyrae stars: Why can't we use these stars?
- Cepheid Variable stars: Why are these better than RR Lyrae stars? What is the "Period-Luminosity Relationship" for Cepheids? How in fact do you use Cepheids to get distances?
- Type-I Supernovae: Why does this work?
- Hubble's Law: How does one use it to get distances to galaxies?

b. Spiral Galaxies

- big blue "pinwheels".
- star forming factories in the current universe.
- know their basic components (rotating disks, bulge, halo)
- how is their atomic & molecular gas distributed? Where are the old stars found?
- spiral density wave triggers star formation

c. Elliptical Galaxies

- big balls of (usually) old stars; very little gas, dust, or star formation.
- the biggest ellipticals are the biggest galaxies known.
- they are dull in optical & infrared images.
- they can be spectacular in radio images!
- the "radio spectacular" ellipticals evidently have a spinning super-massive black hole at their cores that has been consuming stars or gas clouds, triggering the formation of radio jets & lobes.

d. S0 ("S-zero") Galaxies

- intermediate between Spiral & elliptical categories. "Tweeners".
- disks present but also massive bulges.
- small amounts of gas, dust, & star formation, but more than ellipticals.

e. Active Galaxies

- Some galaxies emit more energy from their inner-most regions than from the rest of the galaxy combined.
- What powers this activity? (know the unified scheme)

6. The Large Scale Structure of the Universe (lecture 21)

a. Peculiar Galaxies: Objects that don't fit into Elliptical-Spiral categories

- what forces do we think are responsible for peculiar galaxies?
- Are galaxy collisions really possible? How common are they?
- Do stars ever collide in a galaxy-galaxy collision?
- What is a "Starburst"? How are tidal interactions thought to be responsible?
- How can a galaxy-galaxy collision trigger an Active Nucleus?
- How might galaxy-galaxy collisions form new galaxies?
- What is the possible role played by galaxy collisions/mergers in the actual formation of galaxies?
- How do you make an elliptical galaxy via galaxy collisions/mergers?
- How do you make a spiral galaxy via galaxy collisions/mergers?

b. The Distribution of Galaxies on Large Scales

- Galaxies are not distributed at random in space. They like company.
- using Hubble's Law, large surveys of galaxies have pieced together maps showing how galaxies are distributed.
- galaxy distribution is "frothy" – large regions with very few galaxies ("Voids") and large "Sheets" or "Walls" of galaxies, spanning many Mega-parsecs (Mpc – million parsecs).
- especially dense concentrations of galaxies – called galaxy clusters – stand out.

c. Galaxy Clusters

- know the two basic types of galaxy clusters: their shapes and content. (i.e., which one is rich in spirals and not very concentrated. Which one has ellipticals concentrated in the center, with spirals on the outskirts?).
- remember that galaxy clusters must also have lots of Dark Matter, whose composition we don't know.
- remember also that large galaxy clusters are also filled with an extremely hot ($T > 10^7$ K) gas that emits x-rays.
- this gas follows the distribution of visible galaxies, telling us that the Dark Matter must also follow the galaxies.

d. The "Local Group" of Galaxies

- What sorts of galaxies are the most common in the Local Group?
- Are there any galaxies similar to the Milky Way?

7. The History of the Universe and Life in the Universe (lecture 22)

a. The Cosmological Principle

- what are the three assumptions
- what do they imply about the Universe as a whole? No center, no edge

b. Evidence for the Big Bang: The Three Pillars

- **Hubble's Law**. How does it imply a Big Bang? When did it occur?
- **Cosmic Microwave Background**. What is it? "Blackbody" radiation?
- **Cosmic Nucleosynthesis.** There was no way the observed Helium abundance could be explained by stars. The vast majority of helium in the Universe must have come from somewhere else.

c. Structure Formation

- the early Universe was very uniform & homogeneous. The local Universe is very non-uniform. How did this happen in "only" 14-billion years?
- Random density perturbations in the Dark Matter started to grow over time due to gravity, becoming more massive & larger. Ordinary matter followed, and accumulated into these giant clumps. Simulations suggest that these Dark Matter "halos" accumulated and merged, creating what will eventually become galaxy clusters, Voids, etc.
- Can this Dark Matter be made of Brown Dwarf stars or planets?

d. The Drake Equation

- this is a series of estimates of the likelihood of finding Intelligent Life in the Milky Way galaxy. Understand what each term means. For example what is the habitable zone around a star and why are very small or very large stars a problem? Is there a problem for binary stars? What is the Galactic habitable zone?
- many of the factors are highly uncertain (e.g., the fraction of planets with life that develop "intelligent" life).
- it is still a useful tool for helping think about life in the Universe, and for identifying our "ignorance".