Astronomy 210

Section 1– MWF 1500-1550

134 Astronomy Building

<u>This Class (Lecture 16):</u>

Planet Properties

HW #4 due today!

Turn in the Betelgeuse observation!

<u>Next Class:</u>

Planetary Temperatures

Outline

- Space Exploration
- Planet Properties

Atoms In Perspective

Imagine yourself on a beach. You see the smallest grain of sand that you can find– stuck between your toes. How many atoms does it have? More than…

1. All the people in this room?
2. All the people in Memorial Stadium during a Football game.
3. The population of Chicago.
4. The population of the World.

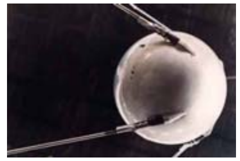
The Top 7 Moons

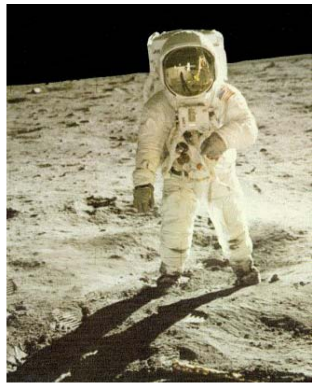
MASS	SIZE
1) Ganymede (0.025)	1) Ganymede (0.41)
2) Titan (0.023)	2) Titan (0.40)
3) Callisto (0.018)	3) Callisto (0.38)
4) Io (0.015)	4) Io (0.28)
5) Moon (0.012)	5) Moon (0.27)
6) Europa (0.008)	6) Europa (0.25)
7) Triton (0.004)	7) Triton (0.21)
Pluto (0.002)	Pluto (0.18)

Jupiter Saturn Neptune In Earth units!

Space Exploration

- Advancements in rocketry after World War II enabled our machines to leave Earth
  - Started with Sputnik in 1957
- We have since traveled to the Moon and the other planets…
- And to the very edge of the solar system

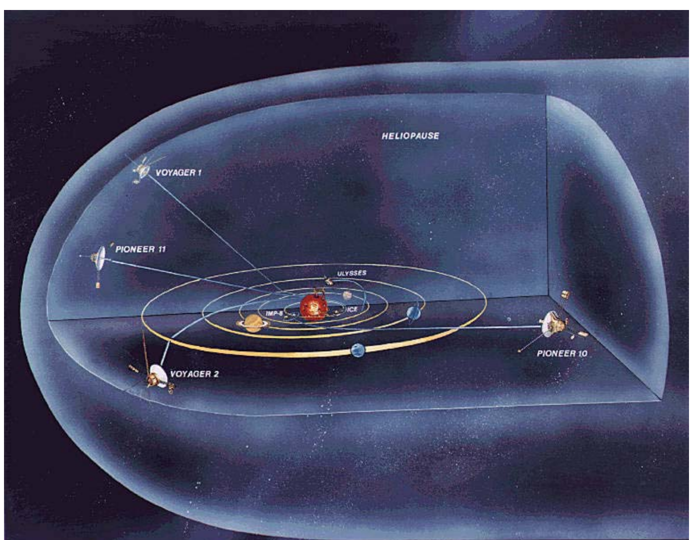




Exploring the Solar System

- Our spacecraft have orbited and landed on Venus, Mars, and Titan, explored the Sun's environment, observed comets, and asteroids, and made close-range surveys while flying past Mercury, Jupiter, Saturn, Uranus and Neptune
- These travelers have greatly increased our knowledge and understanding of the solar system

The Edge of the Solar System



Understanding Earth

- We explore the solar system (and the Universe) to better understand our own planet
- We can’t do experiments *on* our planet
  - Well, other than the ones humans do just by existing…
- Fortunately, nature has created a number of natural experiments for us to explore and learn from

Some Other Benefits of Space Exploration

- High-tech jobs
- Encourages science education
- Technology
  - Electronics: rechargeable batteries, the cordless drill, reverse cycle air-conditioning
  - Health-care: cardiac monitoring equipment, pacemakers, artificial hearts, robotic surgical tools, bone research, etc..
  - Fire-resistant blankets, light composite materials, Gore-Tex
- International goodwill

Group Activity

Space exploration is still a risky and costly business. The estimated cost of transporting a gallon of water to the Moon is $80,000! Estimate the cost of taking a single day's supply of water for your group to the Moon. Remember to include flushing the toilet, showers, laundry, cooking, etc…

Cost estimate is based on weight. How much would it cost to bring back 1g of gold from the surface? On Earth, gold costs about $15/gram.

The Mission

Rice University, Houston TX, September 12, 1962

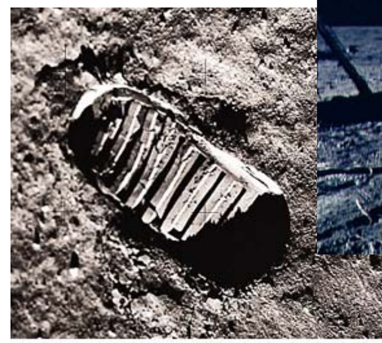
The Launch

July 16th, 1969 9:32am

We Accepted the Challenge

Neil Armstrong, en route to the Moon

One Small Step…



We came in peace for all mankind…

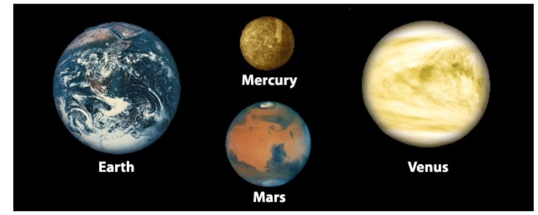
In Memory of Those Who Have Given Their Lives…

- Valentin V. Bondarenko
- Virgil I. "Gus" Grissom, Edward H. White II, Roger B. Chaffee (Apollo 1)
- Vladimir M. Komarov (Soyuz 1)
- Georgi T. Dobrovolsky, Viktor I. Patsayev Vladislav N. Volkov (Soyuz 11)
- Francis R. "Dick" Scobee, Michael J. Smith, Ellison S. Onizuka, Judith A. Resnik, Ronald E. McNair, Gregory B. Jarvis, S. Christa McAuliffe (Challenger)
- Rick D. Husband, William C. McCool, Michael P. Anderson, David M. Brown, Kalpana Chawla, Laurel B. Clark, Ilan Ramon (Columbia)

21st Century View

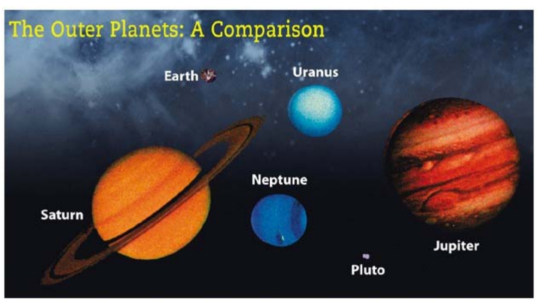
- Six *families* of the solar system
  - Star
  - Rocky planets
  - Asteroid belt
  - Gas giant planets
  - Kuiper belt
  - Oort cloud

The Terrestrials



- Mercury, Venus, Earth, & Mars
  - Plus the Moon, if you want
- The closest planets to the Sun
- Small bodies, made mostly of rock and iron
- Very similar to each other in overall composition and structure
- Vastly differing surface conditions

The Outer Planets



- You've probably heard the outer planets referred to as a single group
  - The Jovians
  - The Gas Giants
- However, Jupiter and Saturn are very different worlds than Uranus and Neptune
- We will consider them as two groups

First Pictures of Pluto/Charon

Planetary Properties

Properties	***Terrestrial***	***Jovian***	***Pluto***
Sun Dist. (avg)	0.4 to 1.5 AU	5.2 to 30 AU	39 AU
Radius	~ Earth	4 to 11 Earths	~0.2 Earths
Mass	≤ Earth	15 to 300 Earths	~0.003 Earths
Density	3000-5000 kg/m^3	~1000kg/m^3	2000kg/m^3
Interior	rocks/metals	gas/ice/metal	?
Spin Period	≥ 1 day	≤ 1 day	6 days
Atmosphere	none/CO_2/O_2/N_2	H_2/He/H stuff	methane CH^4

How do we know these facts?

Adding Distance to Table

- Triangulation
  - e.g. Venus.
    - When the angle is largest, the orbit is tangent to line of sight.
    - Then, $\sin\alpha = a_{Venus}/a_{Earth} \Rightarrow a_{Venus} = 0.72$ AU
- Radar Measurements
  - Shoot a radar signal at planet.
  - How long does it take to bounce back.
  - e.g. find twice the difference between Earth/Venus

Adding Radii

- Once we know the distance, can measure angular size of the planet.
  - Can measure occultation of planet (e.g. Venus with Sun on June 8th 2004)

Or, a Lunar occultation of Jupiter in 1998

http://www.vt-2004.org/central/cd-videos/
http://www.sas.org.au/renato/renato.htm

Adding Mass

- If the planet has an orbiting satellite (moon), we can measure P and a, so:

$$\frac{a^3}{P^2} = \frac{G(M+m)}{4\pi^2} \approx \frac{GM}{4\pi^2}$$

- Don't need mass of the satellite

Adding Average Density

- With size and total mass, can calculate the average density

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- Note: density $\Rightarrow$ composition connection
- All else being equal
- Denser means richer in heavy elements
  - Water (H_2O): 1000 kg/m^3
  - Rocks (O,Si): ~3000 kg/m^3
  - Metals (Ni,Fe): ~6000 kg/m^3

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$\Rightarrow$ Adds compositions to table!

Adding Spin Rate

- Doppler measurement
- At equator, a spinning planet will have

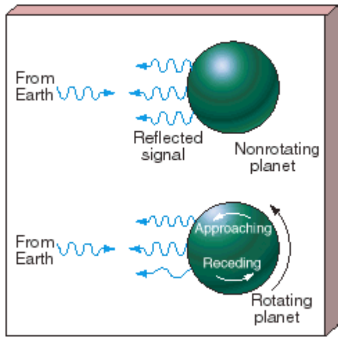
$$v = 2\pi R / P$$

- We will observe the 2 edges of the disk, broadening the wavelengths observed. If cloudy, use radar.

$$v_{receding} = -2\pi R / P$$

$$v_{approach} = +2\pi R / P$$

$$\frac{\delta\lambda}{\lambda} = \frac{4\pi R}{cP}$$



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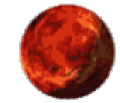
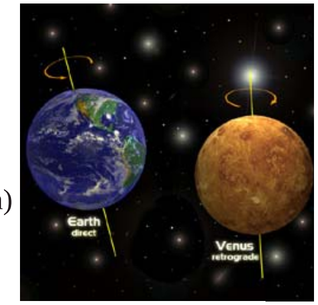


- We can find that Venus rotates in 243 days.
- Almost all planets spin in same direction as orbit
  - Venus – retrograde (opposite or upside down)
  - Uranus – sideways
  - Pluto – retrograde



http://www.windows.ucar.edu/kids_space/images/ask_retrograde_sm.jpg

Adding Temperature

How do you think we can measure temperature of the planets?

Adding Temperature

- Not Wien’s law simply.
- Earth is blue, but that doesn’t mean it is 7000K! Why?
- Reflection of sunlight plays an important role.
- But in the infrared, the emission is more BB. Why?
- What determines temperature of the planets?

Temperature

- Why would the planets have a temperature?
  - Equilibrium between absorption and emission.
  - How much energy is absorbed?

d

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d

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What is A for a blackbody?

A for a mirror?