Bit of Administration ....

- **Washburn Observatory**
  - Thursday, 8:30 - 9:30

- **Portfolios**
  - Due **Thursday, April 29**, because of possible TAA strike
    - Put in box outside 6522 Sterling
  - All 5 must be **securely** bound together, including ones already graded
  - Late portfolios will lose credit

- **Lab 3**
  - Due **Thursday, April 29**, because of possible TAA strike
    - Put in box outside 6522 Sterling
  - Problem 5, HW 1 is a good starting point for the lab questions
  - Note typo in Question 3 - “Jupiter” => “Saturn”
THE EXTRA-SOLAR PLANET PROJECT

• **Phase 1:** Last week’s quiz.

• **Phase 2:** A Web-Lecture on Extra-Solar Planets.
  – Learn about extra-solar planets and have opportunity to earn 5 pts extra credit.
    • 2 pts for evaluation questions
    • 3 pts for success on quiz
  – Preparation for next week’s discussion sections (5/3-5/7).
  – Access: [http://eteach.engr.wisc.edu/meibom/espp/index.html](http://eteach.engr.wisc.edu/meibom/espp/index.html)
  – Speed: 300 Kbps, 100 Kbps, and 37 Kbps.

• The **hardware requirements for viewing the lecture are:**
  – A computer with connection to the Internet.
  – Computer speakers or headphones.

• The **software requirements for viewing the lecture are:**
  – Windows Operating System.
  – Internet Explorer version 5.5 or later.
  – Power Point 2002 or later ("Power Point Animation plug-in").

• **Campus computer-labs:**
  – Bring headphones!
Asteroids, Comets, Meteors, and Pluto
As it contracts, the cloud heats, flattens, and spins faster, becoming a spinning disk of dust and gas. Large, diffuse interstellar gas cloud (solar nebula) contracts under gravity. Sun will be born in center. Planets will form in disk.

Warm temperatures allow only metal/rock “seeds” to condense in inner solar system. Cold temperatures allow “seeds” to contain abundant ice in outer solar system.

Hydrogen and helium remain gaseous, but other materials can condense into solid “seeds” for building planets.

Solid “seeds” collide and stick together. Larger ones attract others with their gravity, growing bigger still.

Terrestrial planets are built from metal and rock. The seeds of jovian planets grow large enough to attract hydrogen and helium gas, making them into giant, mostly gaseous planets; moons form in disks of dust and gas that surround the planets.

Solar wind blows remaining gas into interstellar space. Terrestrial planets remain in inner solar system. Jovian planets remain in outer solar system. “Leftovers” from the formation process become asteroids (metal/rock) and comets (mostly ice).
Asteroids, Comets, Meteors, and Pluto

• Asteroids
Asteroids, Comets, Meteors, and Pluto

• Asteroids

QuickTime™ and a Cinepak decompressor are needed to see this picture.
Asteroids, Comets, Meteors, and Pluto

• Asteroids

• 150,000 catalogued as many as “grains of sand on the beach”
• Size - few km typical, 1000 km largest (half Pluto)
Asteroids, Comets, Meteors, and Pluto

- **Asteroids**
  - 150,000 catalogued, as many as grains of sand on the beach
  - Size - few km typical, 1000 km largest (half Pluto)
  - Density - 2 - 3 gm/cm³
    - Note: About as expected for rock in low gravity
  - Shape - Irregular because of low mass => low gravity
Asteroids, Comets, Meteors, and Pluto

- Asteroids
- Orbits
Asteroids, Comets, Meteors, and Pluto

- Asteroids
  - Orbits - Earth-Crossing Asteroids
Asteroids, Comets, Meteors, and Pluto

- Comets
Asteroids, Comets, Meteors, and Pluto

Ices and Rock
Icy Planetesimal

Tail forms, pushed out by solar wind and radiation; distance is now about 1 AU

“Nucleus”

Coma
Plasma (Gas) Tail
Dust Tail

10 km

Ices and Rock
Icy Planetesimal
Asteroids, Comets, Meteors, and Pluto

• Comets
  • Orbital Properties
    • Long period comets
      • $P \approx 10^5 - 10^6$ yr $\Rightarrow$ $A \approx 10,000$ AU
      • Elliptical to hyperbolic orbits
      • Come from all directions - “isotropic”
Asteroids, Comets, Meteors, and Pluto

- Comets - Oort Cloud
  - Perturbations by passing stars cause comets to fall in
  - Origin of long-period comets

1 trillion comets
Asteroids, Comets, Meteors, and Pluto

• Comets
  • Orbital Properties
    • Long period comets
      • $P \approx 10^5 - 10^6 \text{ yr} \Rightarrow A \approx 10,000 \text{ AU}$
      • Elliptical to hyperbolic orbits
      • Come from all directions - “isotropic”
    • Short period comets
      • $P < 200 \text{ yr} \Rightarrow A < 50 \text{ AU}$
      • Highly elliptical
      • In ecliptic plane
Asteroids, Comets, Meteors, and Pluto

- **Kuiper Belt Objects**
Asteroids, Comets, Meteors, and Pluto

- Kuiper Belt Objects

Oort cloud—A swarm of trillions of comet nuclei in a huge shell surrounding the Sun and planets.
Asteroids, Comets, Meteors, and Pluto

• Kuiper Belt Objects

650 KBOs discovered
100,000 with radii > 10 km
Asteroids, Comets, Meteors, and Pluto

• Comets - Evolutionary Picture
Primordial Icy Planetesimals

Fragmented Icy Planetesimals (KBOs)

Rocky Planetesimals

Jupiter Forms

Icy Planetesimals

Kuiper Belt

Oort Cloud
Asteroids, Comets, Meteors, and Pluto

• Comets
  • Periodic Comets - e.g., Halley’s Comet
    • Highly elliptical
    • P < 200 yr
    • Put into short periods by Jupiter
Asteroids, Comets, Meteors, and Pluto

• Comets
  • Periodic Comets - e.g., Halley’s Comet
    • Highly elliptical
    • $P < 200$ yr
    • Put into short periods by Jupiter
    • Fragmented after many passages
Asteroids, Comets, Meteors, and Pluto

- Meteors
- Showers - debris of old comets
Asteroids, Comets, Meteors, and Pluto

• Meteors
  • Types - Processed Meteorites
    • Stony Meteorites
      • 93%
      • Just like crust of Earth
    • Iron Meteorites
      • 6 %
      • Crystallization patterns => long cooling times
Asteroids, Comets, Meteors, and Pluto

- **Meteors**
  - **Types - Primitive Meteorites**
    - Stony, with trace of pure metallic flakes
    - Carbonaceous chondrites
      - Carbon compounds, and even water
Asteroids, Comets, Meteors, and Pluto

• **Summary**
  - **Asteroids**
    - **Rocky Planetesimals**
  - **Comets**
    - **Long - Period = Icy Planetesimals**
    - **Short - Period = Fragmented KBOs**
  - **Pluto, Sedna, Triton, Kuiper Belt Objects**
    - **Icy Planetesimals**
  - **Meteors**
    - **Primitive Meteors = Rocky Planetesimals**
    - **Processed Iron and Stony Meteorites**
      - Fragmented asteroids
    - **Meteor Showers**
      - Fragmented comets
Asteroids, Comets, Meteors, and Pluto

Jovian Planets Affect Earth Through Their Influence on Small Bodies.

In order to show detail from the inner solar to the Oort cloud, this diagram is NOT TO SCALE.

Oort cloud comets affected by passing stars can also strike Earth.

Asteroid and comet impacts affect geology and biology on Earth.

Jovian planet "nudges" send objects toward Earth and other planets.

Sun

Earth

Asteroid belt (2–3 AU): rocky leftovers of "frustrated planet formation" due to influence of Jupiter's gravity

Kuiper belt (30–100 AU): icy leftovers of the outermost solar nebula; "sculpted" by orbital resonances with jovian planets

Jovian planets

Oort cloud (out to 50,000 AU): icy planetesimals from the jovian planet region ejected by gravitational encounters