Amateur photo of Mars at its last opposition by Alan Friedman

More on Telescopes and Imaging and ... general properties of the solar system
Announcements

- Second homework is due today
  - IF YOU ACCIDENTIALLY PLACED IT UNDER YOUR LETTER IN THE MAIL SLOTS GO AND GET IT NOW AND TURN IT IN CLASS!!!

- Please pickup your past assignments
  - the boxes will be cleared out soon to make room for newly handed-back assignments
  - You can pickup old assignments by coming to my office hours

- Thursday’s reading assignment
  - Sections 7-7, 7-8, 8-1, 8-2, 8-3 and box 8-1 (pp. 160-170)

- Quiz on Thursday
  - Bring a #2 pencil !!!
  - Multiple choice / scantron sheet
Today’s topics

• Telescopes and amateur photography
• General Properties of the Solar System
  – Planetary distances
  – Planet types (terrestrial and gas giants)
    • Volume, density, and mass
    • Distribution of masses and density
Basic Telescope Types

- **Refractor**
- **Reflector**
  - Newtonian
  - Schmidt-Cassegrain (adjacent photo)
Spherical and Chromatic Aberration

- Spherical Mirrors and Lenses do NOT focus light rays to the same point!
- This causes a severe distortion of the image
- Different colors focus at different positions
  - refractors often have this problem
  - Need special lens designs to correct this
The purpose of the **Correcting Lens** (also known as a corrector plate) is to correct for spherical aberration. It dramatically improves the image quality.

Eyepiece lenses are often designed to minimize the blurring effects of chromatic aberration.
• **Light gathering ability**
  - Determines how much light is focused at the eyepiece
  - Larger diameter telescopes gather more light (images are brighter)
  - See section ... of the textbook

• **Resolving power**
  - Determines the smallest visible feature
  - Depends somewhat on the optical design, but generally, larger diameter telescopes are able to see smaller features
  - See page 129 of the textbook
The Effects of Atmospheric Turbulence

- **Spectacular images**
- **Perfect Seeing**
- **Average Seeing**
- **Poor Seeing**
- **Poor Images**

This what a star looks like at very high magnification in a telescope. The different images are for different seeing conditions.
A video of lunar crater *Pitatus* seen through a telescope at high magnification
Hubble Space Telescope

- Perfect seeing – avoids the blurring effects of the atmosphere
- Must be cooled because it radiates as a blackbody and can distort the image!
- Can observe wavelengths (x-rays, UV, and parts of the infrared) that are not absorbed by the atmosphere
Adaptive Optics

- Method for correcting the distorting effects caused by atmospheric turbulence
- “Rubber” Mirrors
- Rapid analysis of incoming image
Images of Neptune with and without Adaptive Optics

(a) Neptune viewed without adaptive optics
(b) Neptune viewed with adaptive optics
Amateur Astrophotography

• 2 basic types
  – **Deep Space Objects**
    • Requires long time exposures, stable mounts, and a precise clock drive
    • Pre-CCD – very difficult, but possible (with patience)
    • Modern CCDs make it much easier
  – **Planetary / Lunar / Solar / Cometary**
    • Shorter time exposures
    • High-resolution images require stable seeing conditions
    • Can use simple webcams
CCD: Charged Coupled Device

- Much shorter exposure times
- Easier computer processing
- What is it?
  - image sensors used in digital cameras.
  - When a picture is taken, the CCD is struck by light and converts it to electrons.
  - The accumulated charge is converted to a digital value.
Webcam imaging
Saturn Through a Webcam
Image Analyzing and Stacking Software (freeware – known as Registax)
Final Image after processing
The Solar System

- There are two broad categories of planets: Earthlike and Jupiterlike.

- All of the planets orbit the Sun in the same direction and in almost the same plane (this is called the ecliptic plane).

- Most of the planets have nearly circular orbits.
Distances from the Sun

- Sun
- Mercury 0.387 AU
- Venus 0.723 AU
- Earth 1.000 AU
- Mars 1.524 AU
- Jupiter 5.203 AU
- Saturn 9.554 AU
- Uranus 19.194 AU
- Neptune 30.066 AU
- Pluto 39.537 AU
Bode’s Law

- A Mathematical representation of the semi-major axis of each planet

- Not a scientific “law” in the usual sense
  - Not based on the laws of physics – it is simply a mathematical construction

- Also known as the Titius-Bode Law

- Start with the simple sequence
  0 3 6 12 24 48 96 192 384

- Then Add 4
  4 7 10 16 28 52 100 196 388

- Then divide by 10
  0.4 0.7 1.0 1.6 2.8 5.2 10.0 19.2 38.8
Bodes Law prediction vs. actual (semi-major axis in AU)

<table>
<thead>
<tr>
<th>OBJECT</th>
<th>PREDICTED</th>
<th>ACTUAL</th>
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</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>0.4</td>
<td>0.39</td>
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<tr>
<td>Venus</td>
<td>0.7</td>
<td>0.72</td>
</tr>
<tr>
<td>Earth</td>
<td>1.0</td>
<td>1.0</td>
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<tr>
<td>Mars</td>
<td>1.6</td>
<td>1.52</td>
</tr>
<tr>
<td>Asteroid Belt</td>
<td>2.8</td>
<td>2.1-3.5</td>
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<tr>
<td>Jupiter</td>
<td>5.2</td>
<td>5.2</td>
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<tr>
<td>Saturn</td>
<td>10</td>
<td>9.5</td>
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<tr>
<td>Uranus</td>
<td>19.6</td>
<td>19.2</td>
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<tr>
<td>Neptune</td>
<td>38.8</td>
<td>30.1</td>
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<tr>
<td>Pluto</td>
<td>78</td>
<td>39.6</td>
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</table>
How do we know what solar-system objects are made of?

- Can determine the mean density and compare it to known elements (like rock, water, and various gases)
  - Need to know the object’s mass and size (which we can get from Kepler’s and Newton’s laws and basic trigonometry)

- Spectroscopy reveals the chemical composition of the planets and/or their atmospheres
Density and Mass

- The average density of any substance depends in part on its composition.
- An object sinks in a fluid if its average density is greater than that of the fluid, but rises if its average density is less than that of the fluid.
- The terrestrial (inner) planets are made of rocky materials and have dense iron cores, which gives these planets high average densities.
- The Jovian (outer) planets are composed primarily of light elements such as hydrogen and helium, which gives these planets low average densities.

\[ \rho = \frac{\text{mass}}{\text{volume}} = \frac{M}{V} \]

Volume of a Sphere = \[ \frac{4}{3} \pi r^3 \]
Two basic classes of Planets
Terrestrial and Jovian (Gas Giants)

• **Terrestrial**
  – Mercury, Venus, Earth, Mars
  – Composed of mostly heavier elements (iron, silicon, etc.).

• **Gas Giants**
  – Jupiter, Saturn, Uranus, Neptune
  – Composed mostly of lighter elements such as H (hydrogen) and He (helium).
Distribution of Planet Masses

<table>
<thead>
<tr>
<th>Planet</th>
<th>Mass (Units of Earth Mass)</th>
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</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>0.055</td>
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<tr>
<td>Venus</td>
<td>0.815</td>
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<tr>
<td>Earth</td>
<td>1</td>
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<tr>
<td>Mars</td>
<td>0.107</td>
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<tr>
<td>Jupiter</td>
<td>318</td>
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<tr>
<td>Saturn</td>
<td>95.2</td>
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<tr>
<td>Uranus</td>
<td>14.6</td>
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<tr>
<td>Neptune</td>
<td>17.2</td>
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<tr>
<td>Pluto</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Mass of Planets (Units of Earth Mass)
Distribution of Planet Densities

• Density = Mass / Volume

![Bar Graph showing the distribution of planet densities with average densities for Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. The x-axis represents the planets, and the y-axis represents the average density in g/cc. The graph compares the densities with a range from 0 to 6.624 g/cc.]
Seven large moons are almost as big as the terrestrial planets

- Comparable in size to the planet Mercury
- The remaining satellites of the solar system are much smaller

<table>
<thead>
<tr>
<th>Table 7-2</th>
<th>The Seven Giant Satellites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moon</td>
<td>Io</td>
</tr>
<tr>
<td>Parent planet</td>
<td>Earth</td>
</tr>
<tr>
<td>Diameter (km)</td>
<td>3476</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>$7.35 \times 10^{22}$</td>
</tr>
<tr>
<td>Average density (kg/m³)</td>
<td>3340</td>
</tr>
<tr>
<td>Substantial atmosphere?</td>
<td>No</td>
</tr>
</tbody>
</table>
Extra slides