Comparative Planetology I:
Our Solar System

Chapter Seven

Guiding Questions

1. Are all the other planets similar to Earth, or are they very
different?
2. Do other planets have moons like Earth’s Moon?
3. How do astronomers know what the other planets are
made of?
4. Are all the planets made of basically the same material?
5. What is the difference between an asteroid and a
comet?
6. Why are craters common on the Moon but rare on the
Earth?
7. Why do interplanetary spacecraft carry devices for
measuring magnetic fields?
8. Do all the planets have a common origin?

There are two broad categories of planets:
Earthlike (terrestrial) and Jupiterlike (jovian)

• All of the planets orbit the Sun in the same direction and
in almost the same plane
• Most of the planets have nearly circular orbits
Density

\[ D = \frac{m}{V} \]

- 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 (Earth-like) planets are made of rocky materials and have dense iron cores, which gives these planets high average densities
- The Jovian (Jupiter-like) planets are composed primarily of light elements such as hydrogen and helium, which gives these planets low average densities

The Terrestrial Planets

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Characteristics of the Planets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The Inner Planets</td>
</tr>
<tr>
<td></td>
<td>Mercury</td>
</tr>
<tr>
<td>Average distance from Sun (10^6 km)</td>
<td>57.9</td>
</tr>
<tr>
<td>Average distance from Sun (AU)</td>
<td>0.397</td>
</tr>
<tr>
<td>Orbital period (years)</td>
<td>0.241</td>
</tr>
<tr>
<td>Orbital eccentricity</td>
<td>0.206</td>
</tr>
<tr>
<td>Inclination of orbit to the ecliptic</td>
<td>7.0°</td>
</tr>
<tr>
<td>Equatorial diameter (km)</td>
<td>48,900</td>
</tr>
<tr>
<td>Equatorial diameter (Earth = 1)</td>
<td>0.950</td>
</tr>
<tr>
<td>Mass (Earth = 1)</td>
<td>0.0553</td>
</tr>
<tr>
<td>Average density (g/m^3)</td>
<td>5.430</td>
</tr>
</tbody>
</table>

- The four innermost planets are called terrestrial planets
  - Relatively small (with diameters of 5000 to 13,000 km)
  - High average densities (4000 to 5500 kg/m^3)
  - Composed primarily of rocky materials

Jovian Planets are the outer planets EXCEPT for Pluto

<table>
<thead>
<tr>
<th>The Outer Planets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jupiter</td>
</tr>
<tr>
<td>Average distance from Sun (10^6 km)</td>
</tr>
<tr>
<td>Average distance from Sun (AU)</td>
</tr>
<tr>
<td>Orbital period (years)</td>
</tr>
<tr>
<td>Orbital eccentricity</td>
</tr>
<tr>
<td>Inclination of orbit to the ecliptic</td>
</tr>
<tr>
<td>Equatorial diameter (km)</td>
</tr>
<tr>
<td>Equatorial diameter (Earth = 1)</td>
</tr>
<tr>
<td>Mass x 10^24</td>
</tr>
<tr>
<td>Mass (Earth = 1)</td>
</tr>
<tr>
<td>Average density (g/m^3)</td>
</tr>
</tbody>
</table>

- Jupiter, Saturn, Uranus and Neptune are Jovian planets
  - Large diameters (50,000 to 143,000 km)
  - Low average densities (700 to 1700 kg/m^3)
  - Composed primarily of hydrogen and helium.
Pluto – Not exactly terrestrial nor jovian

- Pluto is a special case
  - Smaller than any of the terrestrial planets
  - Intermediate average density of about 1900 kg/m³
  - Density suggests it is composed of a mixture of ice and rock

Seven largest satellites are almost as big as the terrestrial planets

<table>
<thead>
<tr>
<th>Name</th>
<th>Mass</th>
<th>EA</th>
<th>GM</th>
<th>Callisto</th>
<th>Titan</th>
<th>Titan</th>
<th>Triton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planet</td>
<td>Earth</td>
<td>Jupiter</td>
<td>Jupiter</td>
<td>Jupiter</td>
<td>Jupiter</td>
<td>Jupiter</td>
<td>Jupiter</td>
</tr>
<tr>
<td>Distance (AU)</td>
<td>3.97</td>
<td>3.05</td>
<td>3.51</td>
<td>3.06</td>
<td>2.09</td>
<td>2.09</td>
<td>2.09</td>
</tr>
<tr>
<td>Mass (10²² kg)</td>
<td>1.35 x 10²²</td>
<td>9.34 x 10²²</td>
<td>4.59 x 10²³</td>
<td>5.53 x 10²³</td>
<td>1.8 x 10²⁷</td>
<td>1.36 x 10²⁷</td>
<td>2.11 x 10²⁷</td>
</tr>
<tr>
<td>Average density (g/cm³)</td>
<td>3.04</td>
<td>3.04</td>
<td>2.74</td>
<td>3.04</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
</tr>
<tr>
<td>Subsatellite</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

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

Spectroscopy reveals the chemical composition of the planets

- The spectrum of a planet or satellite with an atmosphere reveals the atmosphere’s composition
- If there is no atmosphere, the spectrum indicates the composition of the surface.
- The substances that make up the planets can be classified as gases, ices, or rock, depending on the temperatures and pressures at which they solidify.
- The terrestrial planets are composed primarily of rocky materials, whereas the Jovian planets are composed largely of gas
Phases and Phase Diagram

Spectroscopy of Titan (moon of Saturn)

(a) The spectrum of sunlight reflected from Titan

(b) Interpreting Titan’s spectrum
Spectroscopy of Europa (moon of Jupiter)

The spectrum of Europa is almost identical to that of ice, indicating that the surface of Europa is mostly ice, not rock.

Hydrogen and helium are abundant on the Jovian planets, whereas the terrestrial planets are composed mostly of heavier elements.

Jupiter
- Multicolored clouds
- Storm

Mars
- Polar ice cap
- Extinct volcano
- Clouds

Asteroids (rocky) and comets (icy) also orbit the Sun

- Asteroids are small, rocky objects
- Comets and Kuiper Belt Objects are made of “dirty ice”
- All are remnants left over from the formation of the planets
- The Kuiper belt extends far beyond the orbit of Pluto
- Pluto can be thought of as the largest member of the Kuiper belt
- But it’s still considered a planet by IAU agreement
Cratering on Planets and Satellites

- Result of impacts from interplanetary debris
  - when an asteroid, comet, or meteoroid collides with the surface of a terrestrial planet or satellite, the result is an impact crater
- Geologic activity renews the surface and erases craters
  - extensive crating means an old surface and little or no geologic activity
  - geologic activity is powered by internal heat, and smaller worlds lose heat more rapidly, thus, as a general rule, smaller terrestrial worlds are more extensively cratered

Largest Volcano in Solar System (Olympus Mons)

Craters on the Moon
A planet with a magnetic field indicates an interior in motion

- Planetary magnetic fields are produced by the motion of electrically conducting substances inside the planet
- This mechanism is called a dynamo
- If a planet has no magnetic field this would be evidence that there is little such material in the planet’s interior or that the substance is not in a state of motion

- The magnetic fields of terrestrial planets are produced by metals such as iron in the liquid state
- The magnetic fields of the Jovian planets are generated by metallic hydrogen
  - Also hypothesized is water with ionized molecules dissolved in it

The diversity of the solar system is a result of its origin and evolution

- The planets, satellites, comets, asteroids, and the Sun itself formed from the same cloud of interstellar gas and dust
- The composition of this cloud was shaped by cosmic processes, including nuclear reactions that took place within stars that died long before our solar system was formed
- Different planets formed in different environments depending on their distance from the Sun and these environmental variations gave rise to the planets and satellites of our present-day solar system
Key Words

- asteroid
- asteroid belt
- average density
- chemical composition
- comet
- dynamo
- escape speed
- ices
- impact crater
- Jovian planet
- kinetic energy
- Kuiper belt
- Kuiper belt objects
- liquid metallic hydrogen
- magnetometer
- meteoroid
- minor planet
- molecule
- spectroscopy
- terrestrial planet