7. Our Solar System
- Terrestrial & Jovian planets
- Seven large satellites [moons]
- Spectroscopic evidence
- Chemical composition of the planets
- Asteroids & comets

The Terrestrial & Jovian Planets
- Four small terrestrial planets “Like Earth”
  - Relatively close to the Sun
  - Relatively high density (hydrogen-poor)
    - Materials that do form solid surfaces
  - No ring systems
    - Too warm for ices to exist
- Four large Jovian planets “Like Jupiter”
  - Relatively far from the Sun
  - Relatively low density (hydrogen-rich)
    - Materials that do not form solid surfaces
  - Ring systems
    - Primarily H₂O & CO₂ ices

Planetary Sizes to Scale

Planetary Magnetic Fields
- Bar Magnetic Field
- Earth’s Magnetic Field

Planetary Orbits to Scale

The Eight Planetary Orbits
- Highly elliptical, highly inclined orbit
The Seven Largest Satellites

- **Moons in the Solar System**
  - Mercury & Venus have no moons
  - Earth has one moon
  - Mars has two moons
  - Pluto has five moons
  - All Jovian planets have many moons
  - All Solar System moons are terrestrial objects
    - Solid surfaces: Rocks, ices or a mixture of the two

- **Moon sizes**
  - Several dozen planetary moons are quite small
  - Seven planetary moons are quite large
    - Earth: The Moon
    - Jupiter: Io, Europa, Ganymede & Callisto
    - Saturn: Titan
    - Neptune: Triton

Spectroscopic Evidence

- **Basic physical process**
  - Sunlight is reflected by every Solar System object
    - The solar spectrum is very well known
      - Fraunhofer lines: Absorption lines from the Sun’s atmosphere
    - Surface & atmospheric materials absorb some sunlight
      - Many existing absorption lines are enhanced
      - Some new absorption lines are introduced

- **Basic methods**
  - Earth & orbital telescopes operate in many λ’s
    - Visible light: Reflected sunlight
    - Near-infrared “light”: Reflected sunlight
    - Thermal infrared “light”: Emitted by Earth

Spectroscopy of Jupiter’s Moon Europa

- **Photographic evidence**
  - Surface colors & textures resemble Earth’s ice caps

- **Spectroscopic evidence**
  - Near-infrared sunlight is strongly reflected
    - Same spectral curve as sunlight reflected from water ice

Europa’s Spectrum Shows Water Ice

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<th>Diameter (km)</th>
<th>Mass (M⊕)</th>
<th>Average Density (g/cm³)</th>
<th>Substantial Atmosphere</th>
<th>Notes</th>
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Saturn’s Moon Titan
Spectroscopy of Saturn’s Moon Titan

• Photographic evidence
  – Titan has a dense atmosphere
  – Titan has perpetual cloud cover
  • Winds recently detected in Titan’s atmosphere 2002
  • Huygens spacecraft landed on Titan 2005

• Spectroscopic evidence
  – Visible sunlight is strongly reflected
  • Distinct absorption lines appear
    – Methane(CH₄) is very prominent From Titan’s atmosphere
    – Hydrogen (H) is very prominent From Sun’s atmosphere
    – Oxygen (O₂) is very prominent From Earth’s atmosphere
  • Great care must be taken interpreting the evidence
    – Need to know what causes each set of absorption lines
    – Orbiting telescopes eliminate spectral lines from the Earth
    – Orbiting telescopes cannot eliminate spectral lines from the Sun

Influences on Titan’s Spectrum

Planetary Chemical Composition

• Terrestrial planets
  – Atmospheres
    • Mercury Essentially no atmosphere
    • Venus Overwhelmingly CO₂ with variable H₂SO₄
    • Earth ~ 78% N₂ + ~ 21% O₂ + ~ 1% Ar
    • Mars Overwhelmingly CO₂
  – Surfaces
    • Mercury Remarkably similar to Earth’s Moon

• Jovian planets
  – Atmospheres
    • Jupiter & Saturn
      – Rich in H & He but with abundant NH₃ (ammonia) clouds
      – Uranus & Neptune
        – Rich in H & He but with abundant CH₄ (methane) clouds
  – Surfaces
    • Jovian planets have no solid surfaces

Planetary Atmospheres

• Basic physical processes
  – Outgassing Volcanic activity produces gases
    • ~1% to 10% the mass of erupting magma is gaseous
      – Mostly water (H₂O), carbon dioxide (CO₂) & sulfur dioxide (SO₂)
  – Gravity Strong enough to retain gases
    • A function of the mass & diameter of the celestial object
      – Low -mass molecules are most likely to escape H₂
      – High-mass molecules are least likely to escape N₂, O₂, CO₂
  – Temperature Low enough to retain gases
    • Temperature is a measure of average molecular speed
    • Molecules statistically have a range of speeds
      – Low-speed molecules are least likely to escape N₂, O₂, CO₂
      – High-speed molecules are most likely to escape H₂

• Some effects
  – Mercury is too small & hot to retain an atmosphere
  – Most moons are too small to retain an atmosphere

Mars: A Typical Terrestrial Planet

Jupiter: Prototype Jovian Planet
Asteroids

- No clear asteroid ⇔ planet distinction
  - “Minor planets” is a common term
  - Essentially similar to terrestrial planets & moons
    - Extremely hydrogen-poor & therefore high density
    - Relatively close to the Sun & therefore relatively hot
    - Definitely solid surfaces
- Asteroid locations
  - Asteroid belt: Between Mars & Jupiter
  - Earth-crossing asteroids: Between Mars & Venus
  - Moons of Jovian planets: Captured asteroids?

Comets

- No clear ring particle ⇔ comet distinction
  - “Dirty snowball” model of comets
    - Quite different from all other Solar System objects
      - A mixture of ices & rock & metal
- Comet sources
  - Short-term comets: Source: Kuiper belt
    - Less than 200 years to orbit the Sun
  - Long-term comets: Source: Oort cloud
    - More than 200 years to orbit the Sun

Comet Hale-Bopp (April 1997)

Seven Big Trans-Neptunian Objects

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<tr>
<th>Quasar</th>
<th>Kuiper Belt</th>
<th>Oort Cloud</th>
<th>Average distance from the Sun (AU)</th>
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<th>Orbital eccentricity</th>
<th>Inclination of orbit to the ecliptic</th>
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Comet Hyakutake (April 1996)

http://mstecker.com/pages/asthyakutake41996.htm

http://mstecker.com/pages/astr433erosamp.htm

Comet Hale-Bopp (April 1997)

Bluish tail of gas
White tail of dust

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The Unusual Orbit of Eris

- Terrestrial & Jovian planets
- Seven large moons
  - All are terrestrial objects
- Spectroscopic evidence
  - Solar spectrum is very well known
  - Changes are due to what is observed
    - Earth’s own atmosphere
    - Planetary surfaces & atmospheres
    - Water ice on Europa’s surface
    - Methane in Titan’s atmosphere
- Chemical composition of the planets
  - Terrestrial planets
    - Hydrogen-poor & metal-rich
  - Jovian planets
    - Hydrogen-rich & metal-poor
- Planetary atmospheres
  - Outgasing, gravity & temperature
    - Ultimately, gravity is most important

Important Concepts

- Asteroids & comets
  - Minor Solar System bodies