Outline

• Discovery of Uranus & Neptune
• Properties
• Density & Composition
• Internal Heat Source
• Magnetic fields
• Rings
• Uranus’ Rotational Axis
Discovery of Uranus

- by William Herschel (1781) with a 7-inch telescope, while mapping the sky
- “a curious either nebulous star or perhaps a comet”
- Subsequent observations were used to derive a distance from the Sun of 19 AU, which is consistent with Bode’s Law
Discovery of Neptune

• The motion of Uranus could not be accounted for by the gravitational influence of the known planets
• Position of Neptune was determined mathematically by Adams & Leverrier
• Neptune’s distance from the Sun (30 AU) is not consistent with Bode’s Law
## Bode’s Law

### TABLE 1.1 Dimensions of the planetary system

<table>
<thead>
<tr>
<th>Planet</th>
<th>Distance from Sun (million km)</th>
<th>Distance from Sun (AU)</th>
<th>Prediction(^a) from Titius-Bode Rule (AU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>-80</td>
<td>0.39</td>
<td>0.4</td>
</tr>
<tr>
<td>Venus</td>
<td>0</td>
<td>0.72</td>
<td>0.7</td>
</tr>
<tr>
<td>Earth</td>
<td>12</td>
<td>1.00</td>
<td>1.0</td>
</tr>
<tr>
<td>Mars</td>
<td>12</td>
<td>1.52</td>
<td>1.6</td>
</tr>
<tr>
<td>Asteroid belt</td>
<td>330–500</td>
<td>2.20–3.30</td>
<td>2.8</td>
</tr>
<tr>
<td>Jupiter</td>
<td>34</td>
<td>5.20</td>
<td>5.2</td>
</tr>
<tr>
<td>Saturn</td>
<td>54</td>
<td>9.55</td>
<td>10</td>
</tr>
<tr>
<td>Uranus</td>
<td>65</td>
<td>19.22</td>
<td>20</td>
</tr>
<tr>
<td>Neptune</td>
<td>76</td>
<td>30.12</td>
<td>39/77</td>
</tr>
<tr>
<td>Pluto</td>
<td>80</td>
<td>39.44</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Distance (AU) = 0.4 + 0.3 (2^n), where \(n = \infty\) (Mercury), 0 (Venus), 1 (Earth), 2 (Mars), 3 (Jupiter), and so on for the other planets.
Properties of Uranus

• Composition: 84% hydrogen, 14% helium, 2% methane (CH₄) + others

• Average Distance from the Sun: 2.7 light hours

• Orbital Period: 84 Earth years

• Rotation Rate
  \[17^h \text{ – Magnetic Field} \]
  \[16^h \text{ – Clouds} \]

• Axis Tilt: 98° (!!!)

• Number of Moons: \( \sim 27 \)

Note: bluish color is due to methane
Properties of Neptune

- Composition: ~84% (?) hydrogen, ~14% (?) helium, 2% methane + others
- Average Distance from the Sun: 4.2 light hours
- Rotation Rate
  16.8° – Equatorial Clouds
- Orbital Period: 165 Earth years
- Axis Tilt: 27°
- Number of Moons: ~ 13

**Note**: Bluish color due to methane
Storms on Neptune

- Great dark spot
- Clouds: Ice crystals (cirrus clouds) of Methane (?)
Neptune - High Elevation Ice Clouds
Density & Composition

• Densities are high \( \sim 1.3 - 1.5 \text{ g cm}^{-3} \)
• Composition thus cannot be the same as Jupiter & Saturn
• Composition \( \rightarrow \) large core of rock & ice
  \( \rightarrow \) “thin” outer envelopes of liquid & gaseous hydrogen
  \( \rightarrow \) no metallic hydrogen (too small)
Figure 11.5 Comparison of four jovian planet interiors, shown to scale with Earth for comparison.
Internal Heat Sources

- **Uranus** → No.

- **Neptune** → Yes.
  → Primordial *heat of contraction* of ice & rock??
Magnetic Fields

- Magnetic poles are not aligned with rotational poles & are off-axis.

- Cause:
  - pressure ionized ice surrounding rocky core(??)
  - Oceans of hydrogen(??)

*FIGURE 14.16 (a) The magnetic field of Uranus behaves as if there were a bar magnet inside the planet, tipped at an angle of 60° to the axis of rotation and offset as shown in the diagram. (b) To the surprise of most scientists, the magnetic field of Neptune exhibits a configuration very similar to that of Uranus.*
Jovian Magnetic Fields

Source of particles in Magnetic Fields:

- **Jupiter**: solar wind & volcanically active Io.
- **Saturn**: solar wind
- **Uranus**: primarily protons & electrons from hydrogen escaping the planet’s atmosphere
- **Neptune**: protons & electrons from hydrogen escaping the planet’s atmosphere & Nitrogen from Triton’s atmosphere

Source of Magnetic Field

- **Jupiter & Saturn**: metallic hydrogen
- **Uranus & Neptune**: pressure-ionized ice / oceans of hydrogen
Rings of Uranus
Rings wobble

Cause(s): Bulge of Uranus’ disk. Gravitational tug of moons
Rings: Backlit view & Shepherd Moons
Determining structure of Ring – occultation events

- Star
- Motion of Uranus
- Segment of rings
  - 1
  - 2
  - 3
- To planet
- Unobscured star
- Intensity of starlight
- Leading edge of ring 3 crosses star
- Trailing edge of ring 3 crosses star
- Observer
- Time
Occultations
Rings of Neptune: small particles

Planet has been blocked out of this image
Tilt of Uranus’ Rotational Axis

- Seasons last for ~ 20 years
- Cause of Tilt: glancing collision with planet
Air Circulation of Uranus

• Follows rotation, not Hadley cells, similar to Neptune

• Wind speeds highest near poles, not equator. Neptune shows similar rotational structure.

• Temperature → nearly the same at both poles

• We have no clue why any of this is observed
Appended Formation

• Ice & Rock cores built
  → Mass = 10 Earth Masses

• Hydrogen & Helium from surrounding solar nebulae was gravitationally captured
  → Planets that are massive & cold enough can retain hydrogen & helium

• Solid grains in surrounding nebula form satellites

• Uranus & Neptun are less massive because
  → particles more spread out in outer solar nebulae
  → and thus accretion was slower