Astronomy 1 – Winter 2011

Gaseous Pillars in M16 · Eagle Nebula
Hubble Space Telescope · WFPC2

Lecture 17; February 14 2011
Previously on Astro-1

• The satellites of Jupiter and Saturn. A wonderful microcosm of the solar system
  – Jupiter’s giant satellites
  – Crusts and cores
  – Volcanism and internal activity
Today on Astro-1

• Beyond the giant planets
  – Uranus
  – Neptune
  – Pluto and the other TNOs
Outer planets in context
### Table 14-1  Uranus Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average distance from Sun:</td>
<td>$19.194 \text{ AU} = 2.871 \times 10^9 \text{ km}$</td>
</tr>
<tr>
<td>Maximum distance from Sun:</td>
<td>$20.017 \text{ AU} = 2.995 \times 10^9 \text{ km}$</td>
</tr>
<tr>
<td>Minimum distance from Sun:</td>
<td>$18.371 \text{ AU} = 2.748 \times 10^9 \text{ km}$</td>
</tr>
<tr>
<td>Eccentricity of orbit:</td>
<td>0.0429</td>
</tr>
<tr>
<td>Average orbital speed:</td>
<td>6.83 km/s</td>
</tr>
<tr>
<td>Orbital period:</td>
<td>84.099 years</td>
</tr>
<tr>
<td>Rotation period (internal):</td>
<td>17.24 hours</td>
</tr>
<tr>
<td>Inclination of equator to orbit:</td>
<td>$97.86^\circ$</td>
</tr>
<tr>
<td>Inclination of orbit to ecliptic:</td>
<td>$0.77^\circ$</td>
</tr>
<tr>
<td>Diameter:</td>
<td>$51,118 \text{ km} = 4.007 \text{ Earth} \text{ diameters (equatorial)}$</td>
</tr>
<tr>
<td>Mass:</td>
<td>$8.682 \times 10^{25} \text{ kg} = 14.53 \text{ Earth masses}$</td>
</tr>
<tr>
<td>Average density:</td>
<td>1318 kg/m$^3$</td>
</tr>
<tr>
<td>Escape speed:</td>
<td>21.3 km/s</td>
</tr>
<tr>
<td>Surface gravity (Earth = 1):</td>
<td>0.90</td>
</tr>
<tr>
<td>Albedo:</td>
<td>0.56</td>
</tr>
<tr>
<td>Average temperature at cloudtops:</td>
<td>$-218^\circ \text{C} = -360^\circ \text{F} = 55 \text{ K}$</td>
</tr>
<tr>
<td>Atmospheric composition:</td>
<td>82.5% hydrogen ($\text{H}_2$), 15.2% helium ($\text{He}$), 2.3% methane ($\text{CH}_4$)</td>
</tr>
<tr>
<td>Average distance from Sun:</td>
<td>$30.066 \text{ AU} = 4.498 \times 10^9 \text{ km}$</td>
</tr>
<tr>
<td>Maximum distance from Sun:</td>
<td>$30.367 \text{ AU} = 4.543 \times 10^9 \text{ km}$</td>
</tr>
</tbody>
</table>

*Table 14-1*

*Universe, Eighth Edition*

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<table>
<thead>
<tr>
<th><strong>Neptune Data</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average distance from Sun:</strong></td>
</tr>
<tr>
<td><strong>Maximum distance from Sun:</strong></td>
</tr>
<tr>
<td><strong>Minimum distance from Sun:</strong></td>
</tr>
<tr>
<td><strong>Eccentricity of orbit:</strong></td>
</tr>
<tr>
<td><strong>Average orbital speed:</strong></td>
</tr>
<tr>
<td><strong>Orbital period:</strong></td>
</tr>
<tr>
<td><strong>Rotation period [internal]:</strong></td>
</tr>
<tr>
<td><strong>Inclination of equator to orbit:</strong></td>
</tr>
<tr>
<td><strong>Inclination of orbit to ecliptic:</strong></td>
</tr>
<tr>
<td><strong>Diameter:</strong></td>
</tr>
<tr>
<td><strong>Mass:</strong></td>
</tr>
<tr>
<td><strong>Average density:</strong></td>
</tr>
<tr>
<td><strong>Escape speed:</strong></td>
</tr>
<tr>
<td><strong>Surface gravity [Earth = 1]:</strong></td>
</tr>
<tr>
<td><strong>Albedo:</strong></td>
</tr>
<tr>
<td><strong>Average temperature at cloudtops:</strong></td>
</tr>
<tr>
<td><strong>Atmospheric composition</strong></td>
</tr>
</tbody>
</table>

Table 14-2
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HST view of Uranus

South pole

Cloud bands

Northern hemisphere storms

Figure 14-2
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Question 17.1 (iclickers!)

The expected seasonal changes on Uranus because of its orbital and spin axis alignments, compared to those on Earth will be

• A) The same, because the tilt of the spin axis is the same as that of Earth
• B) Much less because its orbit is circular
• C) Absent because the spin axis is perpendicular to the orbital plane
• D) Very much exaggerated, because the spin axis is almost in the orbital plane
Voyager 2 view of Neptune

Great Dark Spot

White clouds

Storm

Figure 14-4
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Figure 14-7
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Question 17.2 (iclickers!)

- Uranus and Neptune are about the same size, yet Neptune shows spots and bands in its atmosphere while Uranus is almost featureless. Why this difference?
  - A) Uranus and Neptune are at vastly different distances from the Sun and the resulting difference in temperature causes the atmospheres to behave very differently
  - B) The two planets, while of similar size, have atmospheres which differ vastly in composition
  - C) The difference can be traced to the fact that Uranus is lying with its rotation axis almost in the planet of its orbit and Neptune is not
  - D) Neptune is still contracting and giving out energy which warms the lower layers of its atmosphere while Uranus is not.
As seen from Earth, the star appears to move along this path behind Uranus and its rings.

Path of starlight to Earth when occultation begins

Intensity of starlight

Unobstructed star

Outer ring

Middle rings

Inner rings

As seen from Earth, starlight dims temporarily when the rings pass in front of the star...

Uranus

Time

...the star's light is completely blocked when it is behind Uranus...

Inner rings

Middle rings

Outer ring

...and the star's light again dims temporarily when the rings on the other side of Uranus pass in front of the star.
<table>
<thead>
<tr>
<th>Interior</th>
<th>Surface</th>
<th>Rings</th>
<th>Atmosphere</th>
<th>Magnetic Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jupiter</td>
<td>Terrestrial core, liquid metallic hydrogen shell, liquid hydrogen mantle</td>
<td>No solid surface, atmosphere gradually thickens to liquid state, belt and zone structure, hurricanelike features</td>
<td>Yes</td>
<td>Primarily H, He</td>
</tr>
<tr>
<td>Saturn</td>
<td>Similar to Jupiter, with bigger terrestrial core and less metallic hydrogen</td>
<td>No solid surface, less distinct belt and zone structure than Jupiter</td>
<td>Yes</td>
<td>Primarily H, He</td>
</tr>
<tr>
<td>Uranus</td>
<td>Terrestrial core, liquid water shell, liquid hydrogen and helium mantle</td>
<td>No solid surface, weak belt and zone system, hurricanelike features, color from methane absorption of red, orange, yellow</td>
<td>Yes</td>
<td>Primarily H, He, some CH₄</td>
</tr>
<tr>
<td>Neptune</td>
<td>Similar to Uranus</td>
<td>Like Uranus</td>
<td>Yes</td>
<td>Primarily H, He, some CH₄</td>
</tr>
</tbody>
</table>

For detailed comparisons between planets, see Appendices 1 and 2.
* To see the orientations of these magnetic fields relative to the rotation axes of the planets, see Figure 14-8.
If distance to Mercury is scaled to distance to SB, Earth would be 25m away, Neptune 700 miles
Voyager 2 view of Neptune’s Rings
Uranus rings and satellites
Voyager 2 view of Triton

- Cantaloupe terrain
- Dark, windblown deposits
- South polar region
Beyond Neptune
2006 IAU RESOLUTION B5: Definition of a Planet in the Solar System

• Contemporary observations are changing our understanding of planetary systems, and it is important that our nomenclature for objects reflect our current understanding. This applies, in particular, to the designation "planets". The word "planet" originally described "wanderers" that were known only as moving lights in the sky. Recent discoveries lead us to create a new definition, which we can make using currently available scientific information.
2006 IAU RESOLUTION B5: Definition of a Planet in the Solar System

• The IAU therefore resolves that planets and other bodies, except satellites, in our Solar System be defined into three distinct categories in the following way:
  – (1) A planet is a celestial body that
    • (a) is in orbit around the Sun,
    • (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and
    • (c) has cleared the neighborhood around its orbit.
  – (2) A "dwarf planet" is a celestial body that
    • (a) is in orbit around the Sun,
    • (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape,
    • (c) has not cleared the neighborhood around its orbit, and
    • (d) is not a satellite.
2006 IAU RESOLUTION B5: Definition of a Planet in the Solar System

- The IAU therefore resolves that planets and other bodies, except satellites, in our Solar System be defined into three distinct categories in the following way:
  - (3) All other objects, except satellites, orbiting the Sun shall be referred to collectively as "Small Solar System Bodies".

- Notes:
  - The eight planets are: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.
  - An IAU process will be established to assign borderline objects to the dwarf planet or to another category.
  - Class 3 currently includes most of the Solar System asteroids, most Trans-Neptunian Objects (TNOs), comets, and other small bodies.
2006 IAU RESOLUTION B6: Pluto

• The IAU further resolves:
  – Pluto is a "dwarf planet" by the above definition and is recognized as the prototype of a new category of Trans-Neptunian Objects.
  – An IAU process will be established to select a name for this category.
Day 1: Pluto appears between these two stars.

Day 2: Pluto has moved relative to the stars.
Hubble Space Telescope images of Pluto’s two hemispheres.

Computer processing shows dark and bright areas on the two hemispheres.
Question 17.3 (iclickers!)

Charon is about 1200 km in diameter and is about 18490 km away from the surface of Pluto. How large an angle does it subtend when viewed from Pluto?

A) 37 arcsec
B) 0.5 degrees
C) 3.7 degrees
D) 57 degrees
Summary

• Uranus was discovered by chance, Neptune with calculations! (although probably Galileo saw it!)
• Higher fraction of heavy elements than Jupiter and Saturn
• How did they form?
  – Formed closer in and then thrown out?
  – Young hot star nearby vaporized light elements (but J/S were shielded)
• Tilted and offset magnetic fields (what sustains it?)
  – Reversal?
  – Impact?
• Dark Rings
  – Those of Neptune appear to be evaporating!
Summary

• **Uranus main characteristics**
  – Foggy atmosphere of He H and NH$_3$ - bluish color
  – Tilted axis of rotation (impact?)
  – No internal heat
  – Many satellites, tidally heated in the past?
  – Smaller satellites recently captured?

• **Neptune main characteristics**
  – Similar atmosphere but more weather (maybe due to internal heat)
  – Axis of rotation similar to Earth
  – Many small satellites
  – Most interesting one is Triton; retrograde, hence probably captured;
    • Geyser-like activity from tidal heating
    • Spiraling inward due to tidal interactions!

• **Pluto**
  – Not a planet; small satellites; similar to Triton
The End

See you on wednesday!