Omnis, in exitu eius, pulchrimma
Given that Jupiter and Saturn are balls of hydrogen, what can we say about their internal structure?
At high enough pressures, hydrogen can become a liquid, and even a liquid metal.
The interior structure of Jupiter (and Saturn)
Magnetospheres 1: the Earth and the Van Allen Belts
Magnetospheres 2: the magnetosphere of Jupiter
University of Iowa connection...plasma waves and radio waves with the Voyager spacecraft
Sounds from the Voyager encounter with the Jovian bow shock

University of Iowa space plasma waves
In earlier lectures we saw how much we learned from studies of the Earth’s moon (the Moon). It is the key to understanding the solar system.

How much can we learn from the moons (or satellites) of the other planets?

Of the three solar system objects most interesting from the viewpoint of exobiology (existence of life in outer space), two are satellites of planets. Or possibly 3 of 4. The only one we have discussed is the planet Mars.
Satellites in the solar system are an example of the fact that Nature always has surprises for us. The famous film *2001 A Space Odyssey* was insufficiently imaginative concerning the Galilean satellites of Jupiter.
Why we knew so little about the Galilean satellites prior to the space age.... From Earth, they subtend a very small angle.

During our observing session, the angular diameter of Saturn was 19 arcseconds (remember what an arcsecond is).

At that time, the angular diameter of the moon Titan (the star off to the left that night) was 0.84 arcseconds, smaller than the “seeing disk” due to the Earth’s atmosphere.
The “top 7” moons in the solar system

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Planet</th>
<th>Diameter (km)</th>
<th>Mass (relative to Moon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ganymede</td>
<td>Jupiter</td>
<td>5262</td>
<td>2.03</td>
</tr>
<tr>
<td>Titan</td>
<td>Saturn</td>
<td>5150</td>
<td>1.83</td>
</tr>
<tr>
<td>Callisto</td>
<td>Jupiter</td>
<td>4820</td>
<td>1.46</td>
</tr>
<tr>
<td>Io</td>
<td>Jupiter</td>
<td>3640</td>
<td>1.21</td>
</tr>
<tr>
<td>Moon</td>
<td>Earth</td>
<td>3476</td>
<td>1.00</td>
</tr>
<tr>
<td>Europa</td>
<td>Jupiter</td>
<td>3122</td>
<td>0.66</td>
</tr>
<tr>
<td>Triton</td>
<td>Neptune</td>
<td>2700</td>
<td>0.29</td>
</tr>
</tbody>
</table>
Let’s start with the moons of Jupiter (especially the Galilean satellites)

Virtually nothing was known about the Moons of Jupiter prior to the arrival of spacecraft in the 1970s

- Io
- Europa
- Ganymede
- Callisto
- 8 others known before space age
- A total of 63 now known (mostly tiny)
The Galilean satellites of Jupiter
The Galilean satellites of Jupiter (cont)
Ganymede: largest moon in solar system

Distance from Jupiter = 1080 thousand km,
diameter = 5262
Europa and the origins of life in the universe

Distance from Jupiter = 671 thousand km, diameter = 3122 km
Cracks in the ice crust of Europa

Evidence of water flows from the interior
Views of the cracks from Galileo
Speculations on interior structure of Europa
A future Europa Lander could tell us much about the possible subsurface ocean of Europa.
Speculations on Europa of 4.5 Gyr ago
The lesson from study of the Galilean satellites: the primary geophysical process is tidal flexing or squeezing due to the strong tides of Jupiter. The tides aren’t strong enough to disrupt these satellites, but they do control their geology.
Titan ... moon with an atmosphere
Titan: bright enough to be seen in a Wal-Mart telescope

1944: discovery that spectrum had absorption lines of methane: a moon with an atmosphere. Known to be about twice the mass and about 50 percent larger in diameter
First real look at Titan in 1979 with Voyager flyby

Atmosphere so dense the surface is not visible

Atmosphere primarily nitrogen (like Earth) but clouds are aerosols (smog) of some sort
25 years later...another spacecraft on a mission
The Cassini and Huygens spacecraft

The Huygens lander
Concept of the Huygens lander...an artist’s conception
Pictures of Titan from the approaching Cassini spacecraft

Image at infrared wavelengths
A new view of Titan (from close up)
The view from Huygens on the way down
Closer to the surface
Titan has flow channels, too
On the surface

“rocks” are blocks of ice

The most remote human “base” in the universe: nearly a billion miles from the Sun
Cassini radar shows lakes of methane
Recent observations from Cassini show different manifestation of methane lakes: sunlight glints from the lake surfaces.
Reasons for the interest and importance of Titan: it has a dense atmosphere and a “hydrological cycle” based on another compound. Despite its alien nature, in some ways it is the most Earth-like object in the solar system.

A more general reason of interest is that Titan may be a showcase for the organic chemistry which can occur in outer space, even if that organic chemistry never developed to the point of forming life. Finally, it is possible, although only remotely possible, that a form of life has evolved on Titan in which liquid methane and ethane play the role of water for life here on Earth. One of the many arguments against this is that the extreme cold of Titan means that chemical reactions would go very slowly.
The surface of Titan: an artist’s view
What we didn’t get to this semester

• Small solar system objects (Chapter 11). Read it!
• Asteroids
• Comets (important this year... check the skies next November
• Meteors
• Kuiper Belt objects (look at Figure 11.5)
• The formation of the solar system and exoplanets (Chapter 12)