15. Satellites of Giants
Inventory of Moons

- 6 large moons (D>1500 km) — most internally active
- 12 medium (D>300 km) — some activity in past?
- 145+ small (D>1 km) — no internal activity
Large & Medium Moons

- spherical due to self-gravity
- composed of ices & rock
- most* formed in disks around parent planets
- most* orbit in same direction as planets spin

* Triton is exception!
Schematic of Jupiter’s Outer Satellites

University of Hawai’i, Institute for Astronomy

44 New satellite orbits are shown in red

Retrograde satellites

Prograde satellites

Callisto’s orbit

5 million km

The Jupiter Satellite Page
Irregular Satellites of Jupiter

- prograde: dashed
- retrograde: solid
Activity: Galilean Satellites

Wide range of geological activity:

— Io is *most volcanic* object in solar system!
— Callisto exhibits very little activity.
Ganymede and Callisto

Ganymede has a mixture of old and new terrain, and hints of tectonic activity.

Callisto has an old and very heavily cratered terrain, with a possible subsurface ocean.
Europa: an Ice-Covered Ocean?

Exaggerated colors

Fractures in crust

Pwyll: Impact crater

“Natural” colors

Natural and False Color Views of Europa
Europa: Internal Structure

What warms Europa’s subsurface ocean?
Io: Volcanic Moon

Loki Patera: active center

Pele: Io’s largest volcanic plume

Topography and Volcanos on Io
Io: Volcanic Moon

Why so active?
Io is alternately stretched and squeezed in its \textit{elliptical} orbit around Jupiter, creating heat through friction.

Over time, this friction \textit{should} make Io’s orbit more and more circular; what \textit{keeps} Io’s orbit elliptical?
2:1 Mean-Motion Resonance

\[ m_1 = 0.001 \, M \quad m_2 = 0 \quad P_1:P_2 = 2:1 \]
2:1 Mean-Motion Resonance
Laplace Resonance: Io, Europa, & Ganymede

4:2:1 Mean-Motion Resonance
Small Satellites of Saturn

- too small to be spherical
- orbit both directions!

Calypso (22 km)  
Pandora (84 km)  
Telesto (24 km)  

Hyperion (180 km)  
Phoebe (220 km)  
Janus (180 km)
Titan: a Moon With Atmosphere

Thick smog of N₂ and hydrocarbons (CH₄, C₂H₆, etc)!
Hydrocarbon Lakes on Titan

Reflection of Sunlight off Titan Lake

Radar Shows Evidence of Seas
Meandering Riverbeds on Titan
Titan’s Climate

- Surface temperature: $94^\circ \text{K} (-179^\circ \text{C})$
- Clouds of CH$_4$, C$_2$H$_6$, other hydrocarbons
- CH$_4$ falls as rain, forms rivers & lakes
- Seasonal changes in CH$_4$ lakes
- CH$_4$ replenished by cryo-volcanism
**Terrestrial Planet Geology**

- Internal heat, primarily from radioactive decay, can cause volcanic and tectonic activity.
- Only large planets retain enough internal heat to stay geologically active today.
- Example: Mars (photo above) probably retains some internal heat. If it had been smaller, like Mercury, it would be geologically "dead" today. If it had been larger, like Earth, it would probably have much more active and ongoing tectonics and volcanism.

**Jovian Moon Geology**

- Tidal heating can cause tremendous geological activity on moons with elliptical orbits around massive planets.
- Even without tidal heating, icy materials can melt and deform at lower temperatures than rock, increasing the likelihood of geological activity.
- Together, these effects explain why icy moons are much more likely to have ongoing geological activity than rocky terrestrial worlds of the same size.
- Example: Ganymede (photo above) shows evidence of recent geological activity, even though it is similar in size to the geologically dead terrestrial planet Mercury.