The Search for Intelligent Life in the Universe

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Saturn's Satellites and Ring Structure

All bodies are to scale except for Pan, Atlas, Telesto, Calypso, and Helene, whose sizes have been exaggerated by a factor of 5 to show rough topography.

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Distance (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pan</td>
<td>2.22</td>
</tr>
<tr>
<td>Atlas</td>
<td>2.28</td>
</tr>
<tr>
<td>Prometheus</td>
<td>2.31</td>
</tr>
<tr>
<td>Pandora</td>
<td>2.35</td>
</tr>
<tr>
<td>Titan</td>
<td>20.3</td>
</tr>
<tr>
<td>Hyperion</td>
<td>24.6</td>
</tr>
<tr>
<td>Iapetus</td>
<td>59.1</td>
</tr>
<tr>
<td>Phoebe</td>
<td>214.9</td>
</tr>
</tbody>
</table>

E Ring thickness (FWHM)

0 10 20 30 km
0 10,000 km
0 20,000 km
0 30,000 km

Distance from Saturn Center (Rs)
Titan

- Only moon with dense atmosphere, 1.5 Earth’s
- Saturn’s largest satellite, # 2 in Solar System
- Spin is tidally locked with Saturn
- In a 3:4 orbital resonance with Hyperion
- Atmosphere’s existence a result of relatively cold formation temperature and high gravity
- Major gases are N\(_2\) (98.4%), CH\(_4\) (1.6%), Ar
- a high smog (hydrocarbon, tholin) layer
- Lack of noble gases Kr, Xe and Ne suggest atmosphere formed as a result of outgassing rather than by cometary impacts.
- Haze results in anti-greenhouse effect, cooling; haze is opaque in visible, but clear in infrared.
- Methane (CH\(_4\)) is present and must be replenished, indicating volcanos or lakes of methane or ethane (C\(_2\)H\(_6\)).
- Surface temperature is 94 K, methane rain may exist
- Surface is complex, fluid-processed and young (H\(_2\)O and NH\(_3\) volcanos?)
Evidence for $\text{H}_2\text{O}-\text{NH}_3$ sub-surface ocean from ELF (extremely long frequency) radio waves

3400 km radius rocky core surrounded by several ice layers

Ammonia ($\text{NH}_3$) lowers $\text{H}_2\text{O}$ freezing point

Systematic shifts of surface implies crust floats on an ocean
Titan’s Climate

Titan’s year is 30 Earth-years long.

Methane rains and ethane snows onto poles in winter and evaporate during summer.
Hydrocarbon lakes
Titan’s Surface

Surface of TITAN (Orbits SATURN)
Images of the HUYGENS lander, January 14th, 2005
Image Credits: ESA, NASA, JPL, U of Arizona
Image Processing: Craig Carmichael

NASA
Titan’s Volcanoes and Lakes

Cryovolcano Tortula Facula

Cryovolcano Sotra Facula
Life on Titan?

- Conditions on Titan might be suitable for some terrestrial psychrophiles, which utilize organic chemicals for both food and energy.
- Some key elements are liquid reservoirs, organic molecules and energy sources.
- Ultraviolet light reacting with nitrogen and methane produces hydrocarbons, visible as orange smog, which fall onto Titan’s surface.
- Large organic molecules (tholins) with atomic weights up to 10,000 have been found in Titan's high atmosphere, and are possibly responsible for the haze.
- Natural forces, such as shifting continental plates, wind erosion, lakes of ethane and methane, and volcanos, can alter the landscape.
- There may exist hot springs connected to hydrocarbon reservoirs.
- Possible life could produce energy by mixing acetylene ($C_2H_2$), abundant in Titan’s atmosphere, with hydrogen.
- Coldness an impediment, however, with $-180^\circ$ C surface making chemical reactions sluggish at best. Subsurface temperatures in the liquid water layer could be much warmer ($-73^\circ$ C).
- Early Titan was warmer, due to radioactivity and warmer Saturn.
- In future, as Sun warms and brightens, temperatures will increase, reaching $-70^\circ$ C when the Sun becomes a red giant.
Enceladus

- Small size, but geologically active
- Surface 90% reflective due to fresh ice
- Ice volcanoes may be the source of Saturn’s E-ring material
- Presence of low melting-point liquid, not pure water, under surface.
- Tidal resonance with Dione or Saturn may be source of heat
Enceladus erupts
Scientists say subsurface reservoirs of pressurized liquid water could fuel geysers on the Saturnian moon, sending jets of icy material into space.

H2O vapor plume and ice particles

Hydrothermal circulation and convecting ice

Vent to surface

H2O ice

Pressurized H2O pocket

Tidal heating

Hot rock

Tidal heating
Saturn’s E ring with Enceladus

Tethys

Enceladus

south polar jets
Iapetus

- Iapetus has a leading hemisphere which is dark (carbon-rich) and a trailing hemisphere which is bright (ice).
- Dark material may be deposited from matter chipped off Phoebe, a very dark satellite; this matter may also coat Hyperion.

Orbit is highly inclined.

Equatorial bulge
Phoebe and Hyperion

- Small Saturn satellites
- Phoebe has retrograde orbit and very rocky, indicating it is a captured Kuiper Belt object.
- Phoebe is very dark: albedo is 0.06
- Hyperion is 2nd largest irregular body in solar system; Neptune’s Proteus is larger.
Mimas clears the material from the Cassini Division, the gap between Saturn’s two widest rings, because that location is in a 2:1 orbital resonance with Mimas.

Impact that produced the large crater (Herschel) almost completely shattered Mimas; an equivalently-sized crater on the Earth would be as wide as the U.S.
Triton

- Largest satellite of Neptune, 3rd-most massive in solar system
- Only large moon with a retrograde orbit, probably originally a binary Kuiper Belt object that was captured and disrupted
- Decaying orbit will take Triton within Neptune’s Roche Limit, causing breakup in 3.6 Gyr.
- Thin atmosphere of N₂ and CH₄
- Few craters, active N₂, H₂O, CH₄ cryovolcanos and geysers; relatively young surface < 50 million years old
- No tidal heating, but seasonal solar heating creates solid-state (ice) Greenhouse effect; geysers only observed near the subsolar point.
Dark streaks of dust left by nitrogen geysers