Mankind will not remain on Earth forever, but in its quest for light and space will at first timidly penetrate beyond the confines of the atmosphere, and later will conquer for itself all the space near the Sun.

- Konstantin E. Tsiolkovsky
Saturn

Mass: $5.68 \times 10^{26}$ kg
Diameter: 60,268 km
Density: 0.6873 gm/cm³

9.0 AU from the Sun
Rotation: 10.78 hours
Revolution: 29.46 years

“Surface” gravity: 8.96 m/s²
“Surface” Temp: -202° F

Atmospheric Composition:
93% H₂
5% Helium
0.2% Methane
0.1% Water vapor
0.01% Ammonia
0.005% Ethane
0.001% Phosphine
Saturn is a **GAS GIANT**

It is mostly Hydrogen gas.

Its density is less than the density of water.

Saturn is easily identified by its brilliant rings.
Saturn from Earth

- Titan
- Rhea
- Enceladus
- Tethys
- Dione
Three Years of Saturn
Comparison of Planetary Sizes

http://www.rense.com/general72/size.htm
Comparison of Planetary Interiors

http://wapi.isu.edu/Geo_Pgt/Mod11_Jupiter/mod11.htm
Saturn's Atmosphere

- Molecular hydrogen
  - Radius 15,000 km
  - Temperature 15,000 K
  - Pressure $5 \times 10^6$ atm

- Metallic hydrogen
  - Radius 30,000 km
  - Temperature 8000 K
  - Pressure $3 \times 10^6$ atm

- Icy/rocky core
  - Radius 60,000 km
  - Temperature 250 K
  - Pressure 10 atm

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Saturn’s Atmosphere

Like Jupiter, the upper cloud layers of Saturn are colored by Ammonia and other chemicals.
Saturn’s Winds

As on the Earth, the convective motion in conjunction with the Coriolis Force gives Saturn’s atmosphere a banded structure.

Like Jupiter, Saturn’s winds are heated from within.

The winds on Saturn can get up to 1800 km/hr.
Saturn’s Subtle Banding Structure
Hubble Movies of Saturn
A Storm on Saturn
Saturn’s Hexagonal Cloud Structure
Planetary Magnetic Fields
Auroras on Saturn
Auroras on Saturn
Saturn’s Major Moons

Saturn

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.
More Moons...

- Enceladus
- Telesto
- Epimetheus
- Janus
- Tethys
- Calypso
- Pallene
- Methone
- Mimas
- Pandora
- Prometheus
- Atlas
- Pan
- Phoebe
- Ijiraq
- Kiviuk
- Ymir
- Suttung
- Thrym
- Mundilfari
- Narvi
- Tarvos
- Siarnaq
- Erriapo
- Albiorix
- Skadi
- Paaliaq
- Titan
- Hyperion
- Rhea
- Polydeuces
- Dione
- Helene
List of Moons

1. Albiorix  
2. Atlas  
3. Calypso  
4. Daphnis  
5. Dione  
6. Enceladus  
7. Epimetheus  
8. Erriapo  
9. Helene  
10. Hyperion  
11. Iapetus  
12. Ijiraq  
13. Janus  
14. Kiviuq  
15. Mimas  
16. Methone  
17. Mundilfari  
18. Paaliaq  
19. Narvi  
20. Pan  
21. Pallene  
22. Pandora  
23. Phoebe  
24. Polydeuces  
25. Prometheus  
26. Rhea  
27. Siarnaq  
28. Skathi  
29. Suttungr  
30. Tarvos  
31. Telesto  
32. Tethys  
33. Thrymr  
34. Titan  
35. Ymir  
36. S/2004 S7  
37. S/2004 S8  
38. S/2004 S9  
40. S/2004 S11  
41. S/2004 S12  
42. S/2004 S13  
43. S/2004 S14  
44. S/2004 S15  
45. S/2004 S16  
46. S/2004 S17  
47. S/2004 S18  
49. S/2006 S1  
50. S/2006 S2  
51. S/2006 S3  
52. S/2006 S4  
53. S/2006 S5  
54. S/2006 S6  
55. S/2006 S7  
56. S/2006 S8
Rings
Ring Structure

The F, G, and E rings are not visible in this photo. They lie outside rings A-D.
The Rings are VERY Flat

The main rings are VERY flat.

The rings are only 10-30 meters thick compared to their 165,000 mile extent.

This is like spreading a tissue across a football field.
A-Ring with the Moon Atlas

The A Ring is made of icy conglomerates ranging from several inches to 10s of feet across.

The gap is called the Encke Gap and is kept clear by the moon Pan.

The Keeler Gap (near the outer edge) is kept clear by the moon Daphnis.
Encke Gap swept clear by Pan
Spiral Density Waves in the A Ring
Cassini Division

Anything in orbit in the region of the Cassini Division is in a 2:1 resonance with the moon Mimas.

This periodic gravitational tugging keeps that area clear.
A and B Rings
Spokes in the B Ring
The C Ring is much less uniform.

It is composed of particles ranging in size from dust pebbles.
Prometheus (left) and Pandora (right) are shepherding moons as they shepherd the F Ring and maintain its shape.
Shepherding Moons

As the inner moon races past the ring, it speeds up the ring particles moving them to a higher orbit. As the ring particles race past the outer moon, the moon slows them down lowering their orbit. Together, the moons keep the narrow ring focused. Even stranger, the moons sometimes switch places!
Saturn’s Major Rings
Saturn from Above
Saturn’s Family (Mosaic)
Moon Orbits
Roche Limit

E. A. Roche (1820 – 1883): Any object held together solely by gravitational forces cannot orbit a planet within 2.44 times that planet’s radius without breaking apart due to tidal forces.

\[ L_{\text{Roche}} = 2.44 \left( \frac{\rho_{\text{planet}}}{\rho_{\text{satellite}}} \right)^{1/3} R_{\text{planet}} \]

- \( L_{\text{Roche}} \) is the Roche Limit
- \( \rho_{\text{planet}} \) is the planet’s density
- \( \rho_{\text{satellite}} \) is the satellite’s density
- \( R_{\text{planet}} \) is the planet’s radius
Cassini Currently in Operation
The Cassini-Huygens mission is designed to accomplish the most distant landing ever made on the surface of another world. Cassini will orbit Saturn for four years and explore its famous rings. The Huygens probe carries scientific instruments to analyze the atmosphere, weather and surface of Titan, the planet’s largest moon.

The route:
- Venus flyby 20 June 1999
- Maneuver 2 December 1998
- Launch 13 October 1997
- Earth flyby 16 August 1999
- Saturn 25 June 2004
- Jupiter 30 December 2000

Once on the surface Huygens will transmit data back to Cassini for three minutes.

Source: NASA
Our View of Saturn and Moons

Key to Saturnian satellites:  
E = Enceladus  
T = Tethys  
D = Dione  
R = Rhea  
Ti = Titan
Mimas

Mimas is a small moon only about 123 miles across.

Mimas is noticeably egg-shaped!
Mimas

The giant crater is called Herschel. It is 80 miles across, and 6 miles deep!!!

It is named after Friedrich Wilhelm Herschel who discovered Mimas and Enceladus. In 1781 Herschel discovered the Uranus. He also discovered Infrared radiation.
Mimas and the Death Star
Enceladus

Diameter: 310 mi
Mass: $8.4 \times 10^{19}$ kg
Density: $1.24 \text{ gm/cm}^3$
Temp: $-329.8^\circ \text{ F}$
Tidal Locked: 1.37 days

It has a high albedo and reflects most of the Sun’s light back into space.
Enceladus

A false color image.

Here are some cities to give you a sense of scale!
Mimas and Enceladus with the UK
Enceladus’ Disappearing Craters
Samarkind Sulci

These tectonic grooves reminiscent of what is seen on Ganymede separate old cratered regions from smooth new plains.

These grooves are called Samarkind Sulci, and the plain on the left is called Sarandib Planitia.
New Ice in South Polar Region

The bluish stripes in this false-color image are regions of new water ice.

This ice has not yet been contaminated by debris settling from Saturn’s rings.
Enceladus has Water Volcanoes!
The E-Ring

The water from Enceladus sprays into space and forms Saturn’s E-Ring.
Cryo-volcanism

This is one of many hypotheses explaining these water eruptions
Artist’s Conception of Enceladus

http://www.arcadiastreet.com/cgvistas/saturn_050.htm

Walter Myers
Tethys

Diameter: 655 mi
Mass: 7.55 x 10^{20} kg
Density: 1.21 gm/cm^3
Temp: -305° F
Tidal Locked: 1.88 days

Tethys is mostly ice. It is heated by orbital resonances and is thought to have cryo-volcanism as well.

Tethys was discovered by Giovanni Domenico Cassini in 1684.
Ithaca Chasma

Ithaca chasma is 60 miles wide, 2 to 3 miles deep and 1240 miles long.

It goes about 3/4 of the way around the moon!
Artist’s Conception of Ithaca Chasma

Odysseus Basin on Tethys

The diameter of Odysseus Basin is about $\frac{2}{5}$ the diameter of Tethys!

It is thought that Tethys was mostly liquid during The impact otherwise the moon should have shattered.
Dione

Diameter: 700 mi
Mass: $1.05 \times 10^{21}$ kg
Density: $1.43$ gm/cm$^3$
Temp: $-304^\circ$ F

Tidal Locked: 2.74 days

Dione is the second most dense moon of Saturn with Titan being first. Dione is ice with a rocky core.

Dione was discovered by Giovanni Domenico Cassini in 1684.
Like the other moons, Dione is tidal locked, so that one side always faces Saturn.

The leading side of Dione is lightly cratered, whereas the trailing side is heavily cratered.

Shoemaker and Wolfe proposed that Dione was once oriented the other way and flipped once enough mass accumulated on the leading edge.
Dione (above) and Tethys (below)
Rhea

Diameter: 950 mi
Mass: $2.49 \times 10^{21}$ kg
Density: $1.33$ gm/cm$^3$
Temp: $-330^\circ$ F

Tidal Locked: 4.52 days

It is not in any orbital resonance and so it has cooled with no volcanic activity.

Rhea was discovered by Giovanni Domenico Cassini in 1672.
Titan was discovered by Christiaan Huygens in March 1655. It is the only moon in the solar system with a significant atmosphere. Gerard Kuiper used spectroscopy to find that Titan’s atmosphere has methane.

Diameter: 3200 mi
Mass: $1.35 \times 10^{23}$ kg
Density: $1.88$ gm/cm$^3$
Temp: $-288^\circ$ F
Tidal Locked: 15.94 days
Atmos. Pressure: 1.5 atm
Composition: Nitrogen and Methane

Titan was discovered by Christiaan Huygens in March 1655. It is the only moon in the solar system with a significant atmosphere. Gerard Kuiper used spectroscopy to find that Titan’s atmosphere has methane.
Titan and Enceladus
Titan has a Dense Atmosphere

Titan’s dense atmosphere is mostly nitrogen and methane.

Ultraviolet light from the Sun creates more complex organic molecules that form a haze high in Titan’s atmosphere.
Cassini uses Radar to Map Titan

Much like Magellan mapped Venus with radar, Cassini must rely on radar to see through Titan’s thick atmosphere.
Cassini uses Radar to Map Titan

The mapping is performed in swaths, each time Cassini flies by.
Titan Unshrouded
Titan Landform Names

- Fensal
- Quivira
- Aztlan
- Tsegishi
- Menrva
- Omacint Facula
- Bazarrto Facula
- Sinlap
- Coats Facula
- Shiwaani Virgae
- Nath
- Hotei Arcus
- Elila Facula
- Elpis Facula
Mountains on Titan

This is the largest mountain range yet seen on Titan.

It is 100 miles long and about 1 mile high.

The shiny material on the peaks is thought to be methane snow and other ices.
Chains of Mountains on Titan

How do these mountains look different from what you have seen on other moons?
Sand Dunes on Titan

Titan

Earth
Huygens Landing Site

Cassini

NACO SDI

$t+38$ hours
Huygen’s Descent at 50 km Altitude
Methane River from 25 km Altitude
Artist’s Conception of Titan
Huygens landed with a SPLAT! in methane mud at -300°F.

The rock strewn surface is most likely water and hydrocarbon ices.

The plain is probably a drainage basin for nearby methane rivers.
Rivers of Methane and Ethane in Xanadu
Lakes and Seas of Methane and Ethane!
The Kissing Lakes
Lakes in False Color
Ligeia Mare on Titan
Planetary Lake Lander

Ligeia Mare
Huygen’s Descent Movie

Titan versus Earth

[Diagram showing temperature and height comparison between Titan and Earth, with notes on clouds and mountain heights.]
Atmospheric Composition at the Surface
Saturn and Titan
Saturn, Dione, and Titan
Saturn, Titan, and Epimetheus
Titan and Rhea
Titan and Rhea
Saturn, Janus and Titan
Hyperion

Dimensions: 260 x 160 x 140 miles
Mass: $1.77 \times 10^{19}$ kg
Density: $1.4 \text{ gm/cm}^3$

Chaotic Rotation!

Note the strange crater formations. It's not clear exactly how this can happen!
Hyperion

“It is thought that this is a result of thermal explosions where dark materials accumulating on crater floors are warmed by sunlight and melt deeper into the surface, allowing surrounding ice to vaporize away”

This is a false color image. In natural light, Hyperion in reddish in color.

http://www.solarviews.com/eng/hyperion.htm
Iapetus

Diameter: 907 mi
Mass: $1.88 \times 10^{21}$ kg
Density: $1.21 \text{ gm/cm}^3$

Tidal Locked: 79.33 days

Iapetus is strange. Its leading side is dark with a slight reddish color; whereas the trailing side is light.

Iapetus was discovered by Giovanni Domenico Cassini in 1671.
The dark material must be constantly renewed, otherwise a meteor impact would blast it away revealing a light surface.
Iapetus
Phoebe

Diameter: 137 mi
Mass: $4.0 \times 10^{18}$ kg
Density: 0.7 gm/cm$^3$

Rotation: 0.5 days
Revolution: -550.5 days (Retrograde orbit)

Phoebe’s low density implies that it is one of the icy planetesimals similar to a comet.
Note how the craters look so different. There is very little gravity here.
Saturn Eclipses the Sun
Earth!