Saturn

- Physical Properties
- Atmosphere (features & weather)
- Interior
- Magnetosphere
- Rings system
- Moons

Exploration by Spacecrafts

**Pioneer & Voyager (1970s)**
- Pioneer 10 (March 1972)
- Pioneer 11 (April 1973)
- Voyager 1 (March 1977)
  Went up to Titan (Saturn’s largest moon)
- Voyager 2 (July 1977)
  Also visited Uranus & Neptune

**Cassini**
- (Launched in 1997 and will arrive at Saturn in 2004 and dispatch a probe built by ESO)
Physical Properties

- Semimajor axis of orbit around Sun: 9.5 AU
- Mass: $5.7 \times 10^{26}$ Kg (95 times that of the Earth)
- Average density: $700 \text{ kg/m}^3$ (0.13 times that of the Earth & less than water)
- Rotation period: 10 hrs 14 min at equator, 10 hr 40 min at poles
- Equatorial radius: ~ 60,268 km (9.5 times that of Earth)
- Polar radius ~ 54,000 km (10% less than the equatorial radius)

*Saturn is noticeably oblate (“flattest” planet in the solar system)*

- Surface gravity (at cloud tops): 10.4 m/s$^2$ (1.07 times that of Earth)
- Magnetic field: ~ 0.7 times that of Earth
- Surface temperature: 97 K (at cloud tops)
  
  (273 K is freezing, 373 K is boiling, 0 K is absolute zero)
- Moons: 30 (total at last count) (one large moon- Titan, 6 medium size moons)
- Axial tilt: 27°
- Sidereal orbit: 29.4 Earth years
- Synodic period: 378 Earth days (time between oppositions)

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Features of Saturn

Saturn is much less colorful than Jupiter.

Unlike Jupiter, no obvious large, long-lived "spots" or "ovals" are visible on Saturn’s cloud decks but occasionally they may occur.
Atmospheric Structure

Composition:
- Hydrogen 92.4 %
- Helium 7.4 %
- Traces: methane (0.2%) and ammonia (0.02 %)

As on Jupiter, hydrogen and helium dominate—these gases never escaped from Saturn’s atmosphere because of the planet’s large mass and low temperature.

Low abundance of Helium??

- Haze and clouds thicker than Jupiter’s and less colorful.

Zonal Flow (Weather)

The zonal flow on Saturn is considerably faster than on Jupiter and shows fewer east–west alternations.

- Speed at equator ~1500 km/h
- First westward flows exist at ~ 40° north and south of the equator
Storms on Saturn

The white coloration of these circulating and evolving clouds arose from crystals of ammonia ice.

Saturn - storm

*Hubble Space Telescope image in 1990*
Interior

Saturn reradiates almost three times more energy than it absorbs.

- thinner metallic hydrogen zone than Jupiter:
  - smaller magnetic field
- less self gravity than Jupiter: lower density

Helium precipitation is responsible for depleting the outer layers of their helium content. The same process results in excess energy emission.

Magnetosphere

- Saturn’s basic magnetic field strength is only about 1/20 that of Jupiter, or about 1000 times greater than that of Earth.
- Saturn’s magnetic field is not inclined with respect to its rotation axis.
- Saturn’s magnetic field, like Jupiter’s, is oriented opposite (North to South) that of Earth.
- Extends about 1 million km toward the Sun and is large enough to contain the planet’s ring system and the innermost 16 small moons.
Saturn’s Rings

Rings lie in the equatorial plane, their appearance (as seen from Earth) changes seasonally.

Edge-on

Inclination of Saturn’s Rings

During Saturn’s summer or winter -- rings are at their brightest.
During Saturn’s spring and fall -- the rings are close to being edge-on (seem to disappear altogether.)
Ring System
(The view from the Earth)

Encke gap (300 km)
A ring
Cassini Division
(Brightest) B ring
C ring

Saturn’s Rings Prior to Voyager

- Known to consist of trillions of particles of ice and rock, ranging from boulders to dust particles.
- All particles together orbit around the Saturn like so many tiny moons.
- Their total mass is comparable to that of a small moon.
- Thought to consist of 3 rings (A,B,C)
- Brightness of rings depends on size and number of particles
- Cassini Division and Encke gap both are dark because they are almost empty of ring particles.
Pioneer and Voyager probes, found that the rings are actually made up of tens of thousands of narrow ringlets.

Saturn’s B ring showed a series of dark temporary "spokes". The spokes were caused by small particles suspended just above the ring plane.
Other Ring Discoveries by Space Probes

- Voyager 2 discovered the faint D ring, lying between the C ring and Saturn’s cloud layer.
- And the E ring well outside the main ring structure, associated with the volcanism on the moon Enceladus.
- Saturn’s narrow F ring, discovered by Pioneer 11, lies just outside the A ring. It has a kinked, braided structure, apparently caused by two small Shepherd satellites that orbit close to the ring and prevent it from breaking up.
- Beyond the F ring is the faint, narrow G ring, also discovered by Pioneer 11.

Name’s of Saturn’s rings
Braided F ring

F ring separated from the A ring by about 3500 km.

F ring and shepherd satellite

The two small, dark satellites, each about 100 km in diameter, are called Prometheus and Pandora. They orbit about 1000 km on either side of the F ring, and their gravitational influence on the F-ring particles keeps the ring tightly confined in its narrow orbit.
The **Roche limit** of a planet is the distance within which the planet’s tidal field would overwhelm the internal gravity of a moon, tearing it apart and forming a ring.

**Origin of Rings**

- Rings are quite young — no more than 50 million years old, or 100 times younger than the solar system.
- So they probably aren’t left over from the planet’s formative stages.
- An object (moon, asteroid, comet) ventures too close.
- Inside the Roche limit (about 2.4 times radius of planet), tidal forces exceed self gravity of object.
- The object is torn apart by the planet’s tidal forces.
- Due to the large equatorial bulge, the particles (ice, rock, dust) are forced into the equatorial plane.
- Due to collisions, the ring particles eventually spiral into the planet: they may only last 100 million years.
The Moons of Saturn

- Total Moons at last count: 30, (18 named)

Three natural groups of moons

**Small**
- 11 old & 12 newly discovered (in 2000).
- Irregularly shaped chunks of ice
- Size ~ less than 300 km across
- Motion -- complex

**Medium**
- Number – 6
- Spherical bodies
- Size -- ranging from ~ 400 to 1500 km across

**Large**
- Number – 1 (Titan)
- Spherical body
- Size ~ 5150 km across (Second-largest in the Solar System)

In contrast to Saturn, Jupiter has no "medium" sized moons. The Galilean satellites are large, like Titan, and all of Jupiter’s other satellites are small—no more than 200 km in diameter.

Titan (Saturn’s largest moon)

(From Voyager 2)

- density (1900 kg/m³)
- has an atmosphere thicker and denser than Earth’s
- primarily consists of Nitrogen (90%) and Argon (~10%)
- thick layer of “smog”: hydrocarbons (aerosols)
- Surface temperature ~94 k
- possibility of methane rain, snow and oceans of liquid ethane?
Saturn’s Mid-Sized Moons

- The inner five are tidally locked by Saturn’s gravity into synchronous rotation.
- Their densities are all between 1000 and 1400 kg/m3.
- Rhea: wispy streaks – release of water from interior and condensed on surface.
- Tethys, Dione: maria – due flooding from beneath?
- Iapetus: leading face in orbit much darker than trailing face.

Distance (at planetary radii):
- Mimas (3.1)
- Enceladus (4.0)
- Tethys (4.9)
- Dione (6.3)
- Rhea (8.7)
- Iapetus (59.1)

Enceladus

Reflects almost 100% of the light it receives
- surface covered with tiny ice crystals.
- large scale volcanic activity.
- Saturn’s E ring is unstable because of volcanism
Hershel Crater

(Its diameter is almost one-third that of the moon itself.)

The innermost, and smallest, medium-sized moon.

Saturn’s small moons

- Saturn’s dozen or so small moons, their masses are poorly known.
- composition is similar to the small moons of Jupiter.
- Just 10,000 km beyond the F ring lie the co-orbital satellites Janus and Epimetheus.
Synchronous orbits of small moons

Telesio and Calypso have orbits that are synchronized with the orbit of Tethys, always remaining fixed relative to the larger moon, lying precisely 60° ahead of and 60° behind it as it travels around Saturn. These 60° points are known as Lagrangian points.

Saturn (Two Non-Spherical Moons)

Hyperion (410 x 260 x 220 km)

Helene (40 x 30 x 30 km)

``tumbles”, rather than rotates