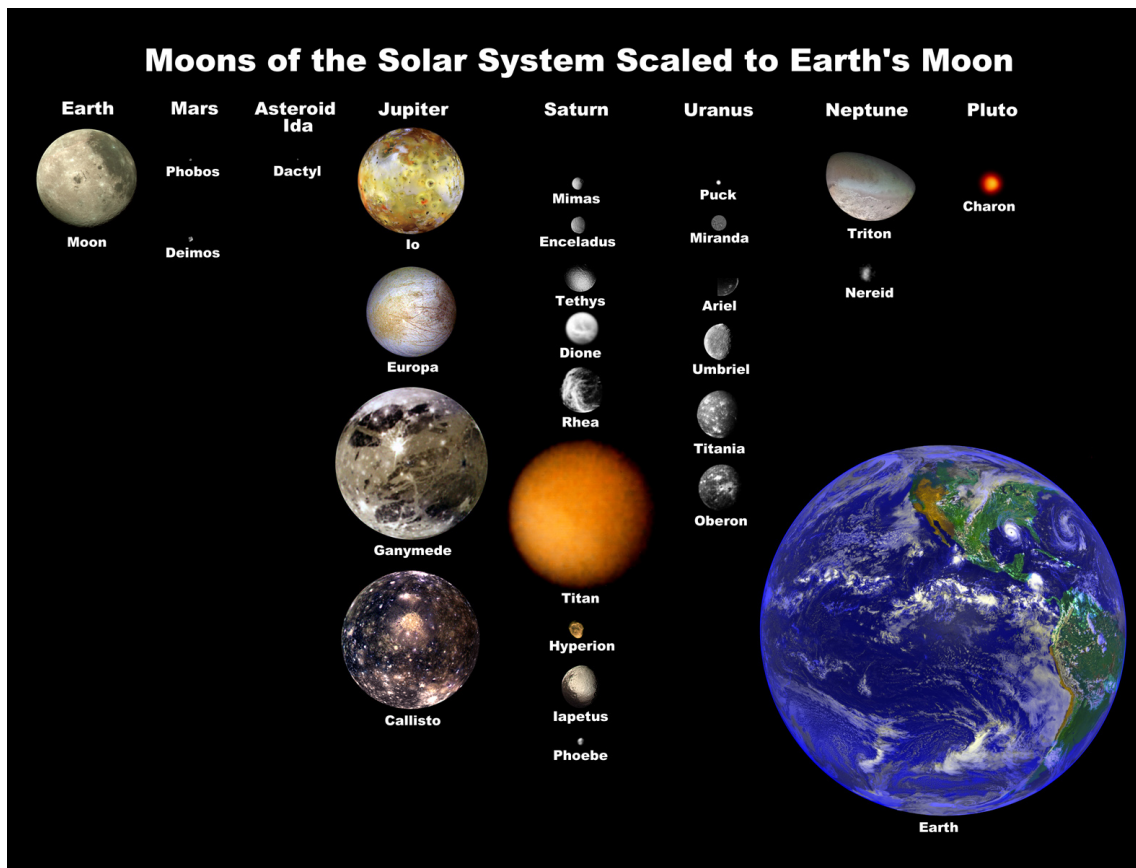


# The most interesting moons in our solar system

Gert Homm

16th October 2006



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# 1 Introduction

In this project it is my aim to give a short review about the, in my opinion, most interesting moons in our solar system. That our moon is not the only one was already noticed in 1610 when Galileo Galilei discovered Io and Ganymed two of Jupiter's moons. Since then there where discovered more than 140 moons, most of them by sending satellites into space.

Most of us know that our solar system contains nine planets and since Pluto is no regular planet anymore there are left only eight, named Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune (ordered beginning with the nearest to the sun). Not every planet possesses moons. Mercury and Venus for example don't have a moon. On the other hand there are planets like Jupiter which have more than 60 moons (63). Of course it is not possible to mention every moon in our solar system within five pages(a list of all moons can be found here [3]), so I limited this project to the, in my opinion, most interesting ones.

But before I start with the terran moon, I will give a short information about some basic terms one should know when talking about moons.

## 2 Basic terms

There are some terms which return again and again in the description of moons and which I now try to explain briefly.

- The **inclination** of a moon's orbit describes the angle between the layer of the moon's orbit and a reference layer, which in most cases is the equatorial layer of the planet.
- A **prograde** moon orbits its planet in the same way like the planet orbits the sun. It is clear that the inclination of such a moon has to be between  $0^\circ$  and  $90^\circ$ . If the inclination is between  $90^\circ$  and  $180^\circ$  then the moon orbits its planet contrarily like the planet does with the sun. This appearance is called **retrograde**.
- A moon is called **irregular** if its orbit is not circular and if its inclination is not small. All **regular** moons are prograde. The inversion is not right (there are some prograde irregular moons).

It exists the convention that all prograde irregular moons are named with an "a" at the end and all retrograde irregular moons' names end with the letter "e" (at least for Jupiter this is true).

## 3 Terran moon

### 3.1 LUNA

The interesting thing about our moon is that it has no real name, since it was the first moon that we discovered. The most used name except "moon" is Luna which is the Latin name for the goddess of the moon.

From an astronomical view it is interesting that the planet Earth is the only planet which possesses just one moon. So Luna and the Earth build the only double-planetary-system in our solar system (since Pluto is no regular planet anymore). Luna is the fifth biggest moon in our solar system and with a diameter of 3475 km bigger than Pluto. Furthermore it is the only object in space except the Earth where a human being put a food on. Of course Luna is the best explored moon in this solar system and one could fill books writing all the facts down

that are known about our moon. But since there are more moons which are interesting I will leave Luna now and continue with Jupiter's moons.

## 4 Some moons of Jupiter's

Jupiter is the biggest planet in our solar system and with a number of 63 it possesses the most moons. In the following I will talk about the most interesting ones.

### 4.1 IO

Io is the most inner moon of Jupiter's and the most interesting thing about Io is its surface. First of all it seems to have no calderas originating from impacts. This means that the surface is extremely young. Nevertheless the surface area has a huge variety. There are caldrons which have a diameter up to 200 km and a depth of several kilometers and are still active volcanos. By now there were discovered more than 300 volcanos that can catapult clouds of smoke more than 300 km high. The thereby ejected material consists mainly of sulfur and its junctions. This material "rains" down again and covers Io's whole surface which causes its blaze of colors (fig. 1).

Furthermore Io's surface contains lakes of liquid sulfur, mountains which have no volcanic origin and lava rivers. These rivers can be hundreds of kilometers long and fluid. They maybe consist of liquid silicate stones or liquid sulfur.

Io's surface temperature is about  $-143^{\circ}\text{C}$ . Anyhow a volcanic eruption can cause temperatures of more than  $1400^{\circ}\text{C}$ , which is about  $200^{\circ}\text{C}$  hotter than a volcanic eruption on Earth and the hottest surface temperature ever measured on a planet or moon in our solar system.

It is assumed that the energy for this volcanic activity comes from the tidal forces between Io, Europa, Ganymed and Jupiter. The periods of these three moons have a resonance that puts Io into a oscillation which in turn causes heat.



Figure 1: Io

### 4.2 EUROPA

Europa is Jupiter's second moon and its especialness is its composition: Its core consists of iron and/or nickel surrounded by a coat of silicate stone. So far this is nothing special but above the coat there is an ocean of salt water or a layer of relatively warm, circulating ice. Finally a at least 19 km thick ice crust leads to the surface. The ice crust together with the ocean are about 100 km thick which make Europa to the most water holding celestial body in our solar system. It even holds more water than the Earth!

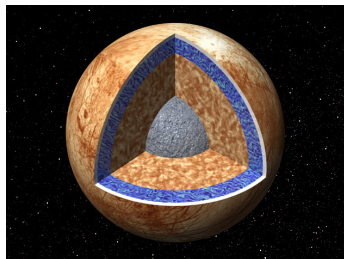


Figure 2: composition of Europa

The same forces that cause volcanic activity on Io may keep the ocean on Europa in a liquid state. At the beginning of the formation of our solar system Europa's surface was covered with oceans. At that time Europa offered the three conditions for life: Water, heat and organic junctions (from comets or meteorites). It is not for sure excluded that life accrued on Europa or still exists there...

### 4.3 GANYMED

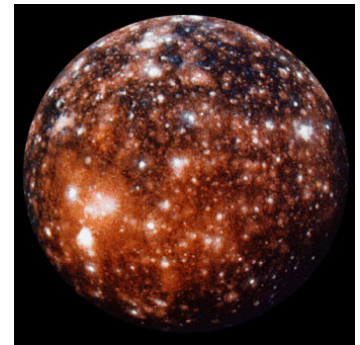
Ganymed is Jupiter's third nearest moon. He (it is the only "male" moon of Jupiter's) is the biggest moon in our solar system. With an average diameter of 5268 km he is of course bigger than Pluto but also bigger than the planet Mercury.

Ganymed's surface is interesting too because it can be separated into two regions: A geologic very old, dark region which contains a huge number of impacts and a, a little bit younger, lighter region with characteristic rifts and faults. The moon's surface consists of two tectonic discs which moved independently. This movement caused mountain ranges. Concerning tectonic activities Ganymed is similar to the Earth although these activities stopped on the moon.

### 4.4 CALLISTO

Callisto is the fourth moon of Jupiter's but with a diameter of 4821 km the third biggest in the whole solar system. Its characteristic is its surface but in a different way than Io's surface. Callisto possesses the oldest surface that is with its four billion years almost as old as the solar system.

Callisto probably has never been geologic active. That is maybe the reason why its surface is littered with calderas. It actually is the moon with the most calderas in our solar system. They originate from the meteoric bombardment of the last four billion years. These calderas are very flat (much flatter than Luna's calderas) which points to a surface consisting of a very smooth ice crust. This ice crust let the deep calderas disappear in the course of time. It is noticeable that some of the calderas shine brighter than others. This is due to the fact that there is an ocean under the ice crust. When an impact was strong enough to break through the ice crust the below lying water could rise to the surface and cause "cleaner" ice than the surrounding dusty ice. This new ice reflects the light better than the old one which leads to brighter shining spots all over Callisto's surface (fig. 3).



**Figure 3:** Callisto

## 5 Some of Saturn's most interesting moons

### 5.1 TITAN

Titan was discovered in 1655 by Christian Huygens. At that time there were known six planets (Mercury, Venus, Earth, Mars, Jupiter and Saturn) and five moons (our moon and the four Jupiter moons described above, discovered by Galileo Galilei). When Huygens discovered Titan he stopped looking for other moons of Saturn's because he thought that there is a special symmetry with six planets and six moons so there should not exist any other celestial body.

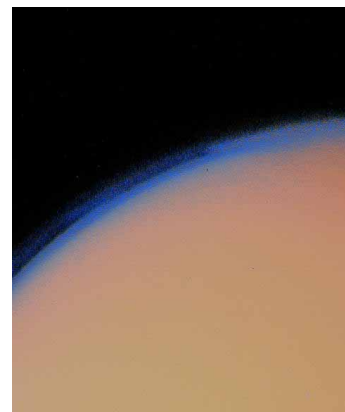
Titan's characteristic is its atmosphere. It is the only moon with a dense atmosphere which is the reason that until 1980 it was thought that Titan is the biggest moon in our solar system. But in 1980 the rocket sonde Voyager 1 showed that Titan's diameter is not 5550 km but "just" 5150 km so it is the second biggest moon after Ganymed but still bigger than the planet Mercury.

As mentioned above Titan is the only moon with a dense atmosphere. Near the ground it is even five times denser than on Earth. All dens layers together build an atmosphere of about 500 km which is again five times thicker than our atmosphere on Earth. The "air" pressure near the ground is higher than 1500 hPa (Earth: 1013 hPa) and in a height of 175 km it is still 1 hPa (on Earth 1 hPa is reached at a height of about 50 km). The atmosphere mainly

consists of nitrogen (near the ground 90%, in the stratosphere 97 % and in the upper layers around 98 %) and methane (near the ground 5 % and in the stratosphere 2 %). In an altitude of about 300 km the nitrogen- and methane molecules can be cracked due to UV-radiation and electrons coming from Saturn's magnetosphere and thereby can form more complex molecules like ethane, propane or cyanic hydrogen. All together this builds a dense, smog-like atmosphere covering the entire moon. (fig. 4)

Titan's atmosphere rotates faster than the moon itself. This phenomenon is called "super rotation" which leads to west winds in a height of 50 km with a speed between 140- and 180 km/h (there even were measured velocities of about 430 km/h). This means that the atmosphere rotates about five times faster than the moon. Of course this super rotation gives titan a characteristic surface.

The big question is why Titan is the only moon with a dense atmosphere. The only moons which come into question are the four big Jupiter moons described above and Triton one of Neptune's moons which I will describe in the next section. It is supposed that Jupiter's moons are too close to the sun. Their attraction forces are not high enough to keep  $-140^{\circ}\text{C}$  cold gases durably. Triton on the other hand is so far away from the sun that its surface is  $-235^{\circ}\text{C}$  cold.



**Figure 4:** Smog above Titan's north pole

Most of the elements are already frozen at these temperatures. Most probably Titan has a hydrologic cycle with clouds, rain and rivers consisting of methane and ethane. But because Titan rotates very slowly and is small comparing to the Earth all processes run very slowly. So there shouldn't be any hurricanes or alternating weather like it is on Earth.

All in all the conditions on Titan are very similar to those on Earth about 3.8 billion years ago. But the temperatures on Titan are about 300 degrees lower (about  $-180^{\circ}\text{C}$ ) so there is no chance for evolution. It is a very bizarre place: The rocks don't consist of stone but of ice. The raindrops who are build in clouds of methane or ethane can be huge (about 1 cm in diameter) and it can take about one hour until they reach the ground because the gravitational force is seven times smaller than on Earth. But in most cases they don't even reach the ground because they evaporate.

When it happens that the raindrops reach the ground they build rivers and lakes made of ethane and methane. So if a future astronaut drove with a motorboat on such a river he would always have enough engine. On Earth the engine has to be refilled on a gas station. On the other hand he would have to carry enough oxygen with him which, alternatively, on Earth would not be necessary.

## 5.2 HYPERION

Hyperion was discovered in 1848 and it is the biggest non spherical moon in our solar system with an average diameter of about 266 km. It is a very porous moon with a small density. It has a characteristic reddish color and its surface is totally covered with calderas which give him its unique sponge-like appearance.

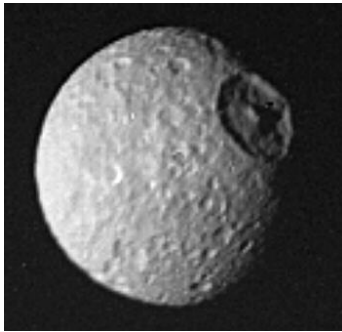
Another interesting singularity of Hyperion is that it has the most eccentric orbit of all regular moons. Furthermore it rotates totally chaotic. That means its axis of rotation changes its orientation in space totally unpredictable and the rotation velocity changes constantly. Let's suppose that somebody lives on Hyperion and plans to have a picnic in about three month. Than he will never know if there is day or night at that time.

### 5.3 ENCELADUS

99 % of the light that falls on Enceladus' surface is reflected. That means that it is the moon with the highest albedo in our solar system. This is due to the fact that Enceladus' surface consists of clean ice and causes an average surface temperature of  $-201^{\circ}$  C. Its surface is with less than 100 million years relatively young which leads to the idea that it is geological active. Furthermore Enceladus possesses a very thin atmosphere consisting mostly of water vapor. It is by far the smallest moon with an atmosphere. But the atmosphere is constantly dispersed over the moon's surface. It is denser above the south polar area. It is amazing that Enceladus possesses an atmosphere at all because his gravitational force is too small to keep one. So there must exist a source which refills the atmosphere constantly. This is a hint for water volcanism. Similar to Jupiter's moons the energy for this water volcanism could be tidal forces between Enceladus his neighboring moons Tethys and Dione and of course Saturn.

### 5.4 MIMAS

Mimas' greatest characteristic is his biggest caldera. It has a diameter of about 130 km which is almost one third of the moon's diameter (397 km). There aren't any bigger calderas comparing to the moon's diameter in the entire solar system because the impact of a body which could cause a bigger caldera would lead to the total destruction of both colliding bodies.



**Figure 5:** Mimas with caldera Herschel

The caldera is named after Mimas' discoverer "Herschel". Its bottom is up to 10 km deep and its edges are about 5 km high. The mountain in the middle soars about 6 km above the caldera's bottom. Because of Mimas' similarities to the "Death Star" in George Lucas' movie "Star Wars" some think that George Lucas may took Mimas as an example. But this is not possible because Mimas' caldera was only discovered in 1980 and Lucas' movie came into the cinemas in 1977.

### 5.5 EPIMETHEUS & JANUS

These two Saturn moons have almost the same orbit. It is possible that they ones were just one moon that as a result of a big collision broke into two pieces. Janus has a diameter of about 181 km and Epimetheus one of about 117 km. The radius of the orbit now differs just about 50 km which is obviously less than their diameters. Furthermore their circulation periods differ a little bit so one can calculate that they should meet about every 4 years. So why do they still exist when they instead should collide?

When they meet instead of a collision something different happens: Just before the inner, faster moon reaches the outer one he receives some angular momentum which puts him on a more outer orbit. This again slows him down a little bit. The other moon however loses angular momentum and so comes to a more inner orbit which accelerates him. In this way the two moons change places at regular intervals without passing each other. A very nice animation can be seen here [4]. The last meeting of the two moons was in January 2006. So far it is not clear if the two moons are in a stable relation or if it will come to a collision one day.

## 6 Some of Neptune's most interesting moons

### 6.1 TRITON

Triton is with a diameter of 2707 km Neptune's biggest moon. Beyond that Triton is the coldest moon in our solar system with a surface temperature of  $-235^{\circ}$  C. This is only 38 degrees warmer than absolute zero. Because of these low temperatures Triton is the only known moon whose surface largely consists of frozen nitrogen.

The space probe Voyager 2 surprisingly noticed geyser-like eruptions. It was found that this is liquid nitrogen which is pressed through a gap in the surface and catapulted up to 10 km high where the nitrogen explosively evaporates. This so called "cryo- volcanism" is due to seasonal heating caused by solar radiation.

Furthermore Triton is the only irregular big moon and with an inclination of  $156.8^{\circ}$  he is retrograde. Triton's own rotation is retrograde too. This property causes tidal forces between Triton and Neptune which dispossess Triton of energy. This causes that the distance to Neptune decreases and in a far future will lead to: Either a breaking apart of Triton and building a ring or a crash into Neptune.

### 6.2 NAIAD & S/2002 N4

These two moons are examples for the shortest (Naiad) and the longest (S/2002 N4) circulation period.

With an orbital radius of 48227 km (about 1.9 times the radius of Neptune) Naiad is nearer to Neptune's surface than the surface to the planet's center. The moon needs for one circulation 0.2944 days which is about 7 hours and 4 minutes.

To come to the other extreme the moon S/2002 N4\* has an average orbital radius of about 1954 times the radius of Neptune's which are about 48 millions km. To give a comparison: The shortest distance between the Earth and Venus is about 38 millions km! But as I said above, this is just the average distance between the moon and Neptune. The most distant point between these two is about 72 millions km (2920 times the radius of Neptune) away from Neptune. That is more than the maximum distance between Mercury and the sun (about 70 millions km). S/2002 N4 needs about 9374 days for one circulation which are 25 years and 8 month. This of course is the longest circulation period in our solar system.

\* This is just a provisional name and means "satellite with the discovery picture from the year 2002, fourth discovery near Neptune"



## 7 References

- [1] <http://www.monde.de/index3.html>
- [2] <http://www.wikipedia.org>
- [3] [http://en.wikipedia.org/wiki/List\\_of\\_natural\\_satellites](http://en.wikipedia.org/wiki/List_of_natural_satellites)
- [4] <http://www.swin.edu.au/ims/astro/satmoonMM.swf>