THE SCOPE

GT Astronomy Club

Remembering Cassini: 20 Years In Space

By Ryan Longood

This past September brought us to the end of one of the most celebrated and successful deep space missions of all time, which began exactly 20 years ago on October 15th, 1997.

Since 2004 when it initially entered Saturnian orbit, the Cassini-Huygens mission (commonly called "Cassini" for short) has provided us with hundreds of gigabytes of data on the nature of Saturn, its satellites, and its rings.

The Cassini-Huygens mission consisted of two distinct physical probes, the Cassini orbiter and the Huygens lander. The latter would become the first ever probe to land on the surface of Titan, and in doing so, has provided us with the first look of Titan's surface. Titan is covered in a thick orange atmosphere that obscures any surface features; as a result, a major mission of Cassini-Huygens was to better understand Titan's surface and the processes that shaped it.

Huygens has helped us do precisely that. Its landing on Titan revealed Titan's atmosphere to be composed of methane and carbon compounds, and revealed its surface to be rocky and eroded similar to Earth's. Although Huygens was not equipped to detect complex organic compounds, scientists believe that Titan's atmosphere resembles that of early Earth's, and some even say that Titan could harbor life under these conditions.

NASA/JPL-Caltech Illustration of Cassini above Saturn's northern hemisphere

Huygens was not intended to last long, unfortunately, and stopped transmitting 72 minutes after a 2.5-hour descent through the atmosphere to its surface after running out of battery power. Cassini, however, was equipped with several long-life radioisotope thermoelectric generators capable of providing reliable power for several decades. This made fuel rather than power the limiting factor for the length of the mission, and due to exceptional fuel conservation, Cassini had its mission lifetime extended from four to a whopping 13 years.

In that time, Cassini was able to provide us with an extraordinary amount of data. Its close flybys of the moon Enceladus revealed several icy geysers erupting from the moon's surface. Further analysis of Cassini's data on Enceladus has led NASA to conclude there is a global liquid ocean beneath Enceladus's surface, which poses as a likely location for extraterrestrial life.

Cassini has also allowed us to more closely study the structure of storms on Saturn. While everyone knows of the Great Red Spot on Jupiter, few know that Saturn has a similar phenomenon called the Great White Spot, a massive storm that recurs about every 30 years. A recurrence of this storm happened between 2010 and 2011, allowing Cassini to give us the first up-close view of the storm. Cassini also gave scientists a glimpse at a storm centered on Saturn's south pole that resembles a hurricane from here on Earth. Saturn's is noticeably stronger however, with a diameter of 5,000 miles and wind speeds up to 350 mph. A similar storm also exists at the north pole, but has an interesting feature the south pole storm lacks: the north pole's storm is hexagonal in shape. While there is plenty of conjecture as to what causes this unusual shape, there is still no scientific consensus on its cause.

Cassini also studied the structure of Saturn's remarkable rings. Like how a tree at sunset has an elongated shadow, the rings of Saturn cast elongated shadows during Saturn's equinox; this magnifies features and allows other features to be viewed that were otherwise invisible. Exploiting this, Cassini discovered that the particles in the rings were much larger than originally thought. Scientists thought the largest of the particles would only be feet across, but Cassini measured particles several miles across instead.

While Cassini's contributions to our knowledge of the solar system are endless, its ever-dwindling fuel supply meant that it eventually had to be decommissioned. Several decommissioning plans were considered, including an orbit around the sun to collect solar wind data and a descent into the atmosphere of Titan, but eventually it was decided to crash Cassini into Saturn to avoid any possibility of biological contamination of Saturn's moons. In its so-called "Grand Finale," Cassini made several daring maneuvers through the rings of Saturn before descending into Saturn's atmosphere on September 15th, 2017.

While Cassini-Huygens may have come to an end, the data it has provided us will continue to be analyzed for years to come. Already Cassini's data has directly led to the publication of nearly 4,000 scientific papers and that number will only continue to grow. Cassini-Huygens has undoubtedly secured its place as one of the greatest scientific endeavors in human history.

Saturn: The Ringed Giant

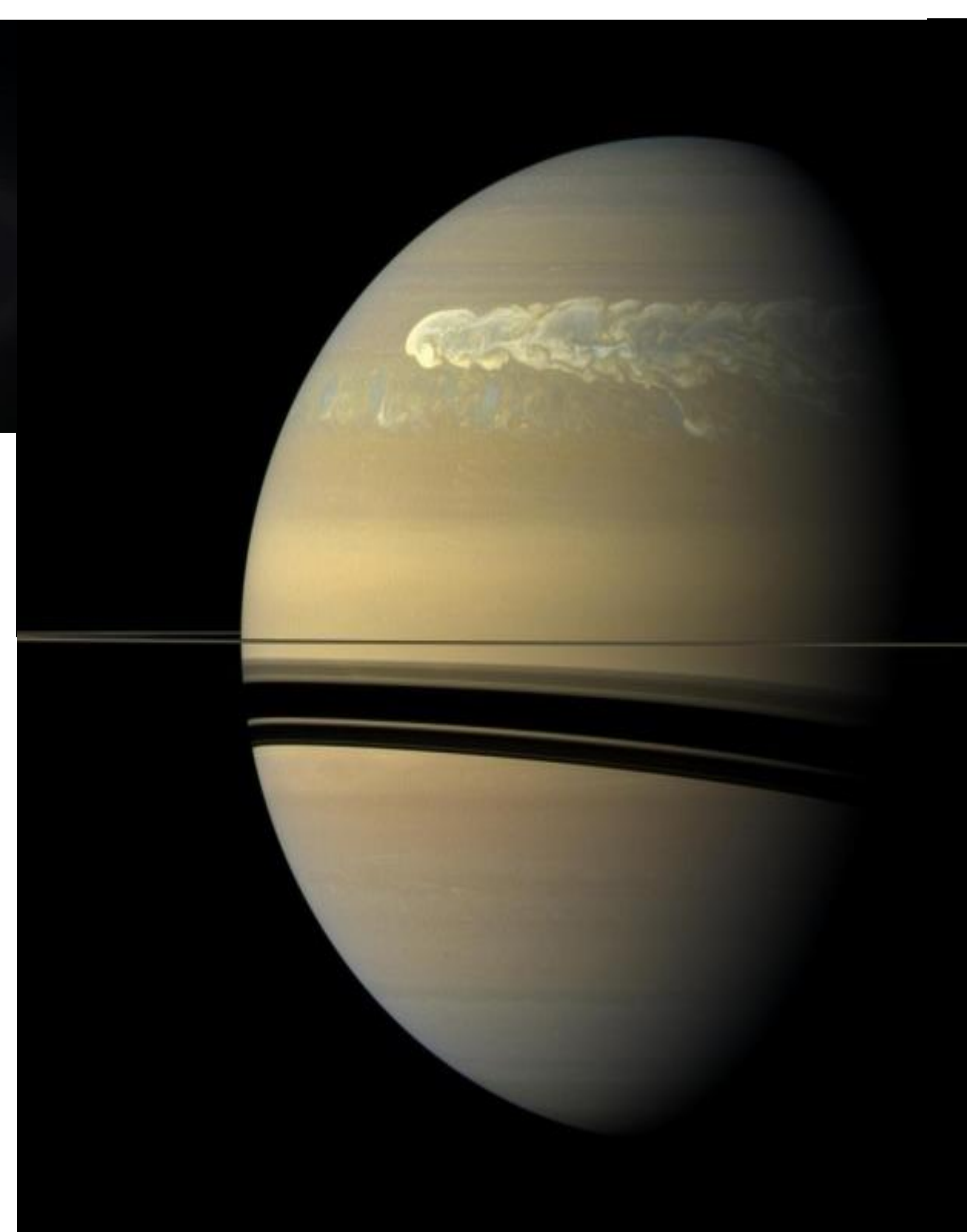
By Joanna Wedemeyer

Located approximately nine Astronomical Units from the Sun, Saturn is the second largest planet in our Solar System with a radius of 36,184 miles. Named after the Roman god of agriculture and harvest, Saturn was officially discovered by Galileo in 1610. However, since it is one of five planets that is visible with the naked eye it is possible that the Ancient Greeks, Egyptians, or Chinese discovered it hundreds of years prior. In 1659 Christaan Huygens distinguished the "arm" of Saturn to be rings, not moons. Since then many discoveries have been made about our "Ringed Planet".

Starting from the inside, the core of Saturn is something that is mostly speculated about. Current theories state that Saturn's core is composed of rock and metal, and is about the size of Earth. Saturn itself does not seem to have much in the way of metals, so it is theorized that through condensation, hydrogen turns into liquid hydrogen rain, and through increased pressure as it falls to the core, condenses into metallic hydrogen. You may wonder why there needs to be any metal at all. The answer can be simplified into this: the magnetosphere of Saturn. While nothing has been set in stone, the prevailing theory of how magnetospheres form is a fast rotating metal plus liquid metal in the core (Earth's core consists of many layers, one of which is molten metal). As Saturn is both fast rotating and has a magnetosphere, there is presumably liquid metal in its core. The temperatures deep near the core of Saturn are as high as 21,000 degrees Fahrenheit. Because of the distance from the Sun, most of Saturn's heat comes from its core. In fact Saturn radiates over twice as much heat as it receives from the sun. This energy may be leftover energy from when it first formed, caused by gravitational compression, however it is also speculated that it may be due to the friction created when helium and hydrogen condense and sink to the core.

Moving out of the core, we enter Saturn's atmosphere. Consisting of mainly hydrogen and helium, Saturn does contain other elements such as methane and ammonia. Some oxygen and nitrogen can also be found. Saturn's atmosphere also consists of three layers of clouds. The upper layer is made of ammonia ice and has temperatures ranging from -280 degrees Fahrenheit to -170 degrees. The second layer consists of water ice intermixed with bands of ammonium hydrosulfide and has temperatures that range from -127 to 26 degrees Fahrenheit. Finally, the lowest level of clouds have higher pressures (equivalent to pressures found deep in Earth's ocean) and temperatures that reach up to 134 degrees. Here, water droplets mixed with ammonia can be found.

Saturn's surface has hosted ginormous thunderstorms over the years, known as Great White Spots (much like Jupiter's Great Red Spot). They occur approximately once every Saturn-year (which is about once every thirty years here on earth). In the 1980s, when the Voyager satellites were travelling to Saturn, it sent back images of a large cloud formation, almost 25,000km across, near the north pole. About twenty-five years after that image, infrared photos taken by Cassini revealed the clouds were a storm that was spinning and was powered by jet streams that pushed it up to speed of 220 mph.



Leaving the atmosphere, the first thing that greets our eyes will be Saturn's moons, and of course its rings. The width of Saturn's rings ranges from 4300 miles from Saturn's equator to 50,000 miles. While Saturn's rings may seem to be solid bands, they are actually composed of many small satellites (bits and pieces of rocks ranging in size from baseballs to houses). Even more interesting, these satellites don't orbit in one giant band, but multiple bands of varying density at different distances from Saturn. There are fourteen major subdivisions of Saturn's rings: D Ring, C Ring, B Ring, Cassini Division, A Ring, Roche Division, F Ring, Janus/Epimetheus Ring, G Ring, Methone Ring Arc, Anthe Ring Arc, Pallene Ring, E Ring, and the Phoebe Ring. It may surprise you to know that even though the rings are discontinuous, they still hold their shape and have done so for many centuries; this is thanks to Saturn's 'Shepherd Moons'. Saturn has a total of fifty-three moons, four of which are classified as Shepherd Moons (Prometheus, Pandora, Pan, Daphnis). These moons exist within Saturn's rings, while the other moons exist outside, with orbits that are typically between two bands of different densities. These shepherd moons knock stray satellites back into the rings, forcing them to keep the the same ring-shape around Saturn that Galileo saw over four-hundred years ago.

Saturn is a unique planet in our Solar System. With rings that are visible from millions of miles away, Saturn is the bright diamond ring in our night sky, and will continue to be so for many centuries to come. I for one am excited to see what new discoveries will be made over the course of the next decade or two.

Above: Storm clouds moving across the northern hemisphere of Saturn by NASA/JPL-Caltech

Upper Right: In Saturn's Shadow by NASA/JPL/Space Science Institute

Information was gathered from sources such as NASA, Space.com, and Dr. Sowell's Solar System Course (Phys 2021).

Titan and the Huygens Probe

By Will Thompson

While Cassini was responsible for providing us with much of the information that we have today about Saturn and its system of moons, the lesser known Huygens probe played a significant role in our exploration of Saturn's moon, Titan. Named after the Dutch Astronomer that discovered Titan, the Huygens probe was constructed by the European Space Agency to perform the unique task of landing on the surface of Titan. To date, Titan is the farthest object that humans have been able to land a probe on as Huygens is the only man-made object to have landed in the outer solar system. It also has provided us with the only images in existence of the surface of Titan, one of the largest moons in the Solar System, second only to Ganymede.

Among the most unusual features about Titan is the fact it has a dense atmosphere, as it is the only known moon with a dense atmosphere that we know of. From the surface of Titan, one would be placed under 1.45 atmospheres of pressure, making it denser than Earth's atmosphere. The composition of this atmosphere is almost entirely nitrogen, which comprises 98.4% of the air, with methane making up the remaining 1.4%. This unique atmosphere also allows Titan to have a weather cycle much like Earth's water cycle, but Titan's cycle involves methane and ethane rather than water. This cycle of hydrocarbons has produced seas, lakes, rivers, and other liquid bodies made of methane and ethane across Titan's surface. The large bodies of liquid methane and etha, located primarily around the moon's southern poles, made Titan the first extra terrestrial body in our solar system that scientists had observed liquid on. As a result, Titan was a prime candidate to send a probe to as a part of the Cassini-Huygens mission.

The Huygens lander was specifically designed to be able to land in the uncommon climate of Titan, even taking into account the risk that the probe might be able to land on a liquid surface. The Surface-Science Package (SSP) was a piece of equipment on the Huygens probe which were designed to determine the physical structure that it landed on. The particular instrument activated 100 meters above Titan's surface and continually scanned the surface below Huygens to determine whether or not the probe would be landing on a hard rocky surface or in one of the methane lakes. In addition to measuring the surface, the SSP also measured the speed of sound during the descent of Huygens in order to determine the atmospheric composition of Titan. In fact most of Huygens' equipment, ranging from a gas spectrometer to a wind experiment were designed to measure the various aspects of the large moon's unique atmosphere.

The actual mission of the Huygens was fairly short lived. According to the data at the European Space Agency, Huygens descended through Titan's atmosphere roughly one year after it had arrived in orbit around Saturn with Cassini. It took about 21 days to reach Titan after it disconnected from Cassini and took 2 hours and 27 minutes to travel through Titan's atmosphere to the surface. On January 14, 2017 the Huygens lander ended an 8 year journey as it reached the surface of Titan and was able to transmit data to Earth, which was relayed through the Cassini orbiter. Huygens was able to continuously transmit data for 72 minutes before Cassini moved out of range and contact was lost with the probe. During that brief time period, Huygens was able to provide some of the most detailed information used to advance our understanding of Titan.

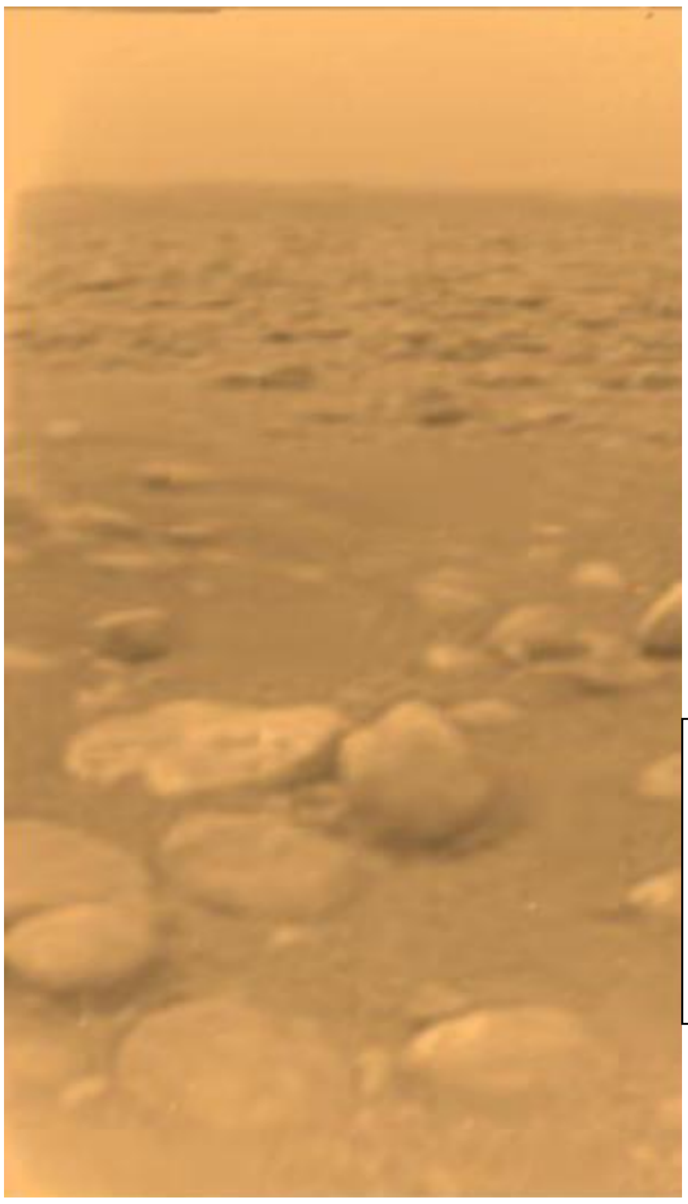


Image Taken from the Surface of Titan by the Huygens lander

Credit: ESA/NASA/JPL/University of Arizona

Enceladus

By Thomas Orchard

Much like Michael Jackson in the Jackson 5, Enceladus is not the biggest of Saturn's moons, but it is the star of the show.

Named after the giant Enceladus in Greek mythology, it is the 6th largest of Saturn's moons at around 500km in diameter. What distinguishes Enceladus is its unique composition; an icy world with hydrothermal vents that eject water vapor into space from an underground ocean lurking beneath the glassy surface. Based on observations from the Cassini spacecraft, the vents eject material as far as three times the radius of Enceladus and erupt continuously, spewing gases, organic compounds and silica. Observations tell us that this material can be ejected at speeds of up to 800 miles an hour (almost twice as fast as some commercial jets). In fact, such is the power and reach of these eruptions that the ice clouds and dust form a part of Saturn's rings – specifically part of the E-ring.

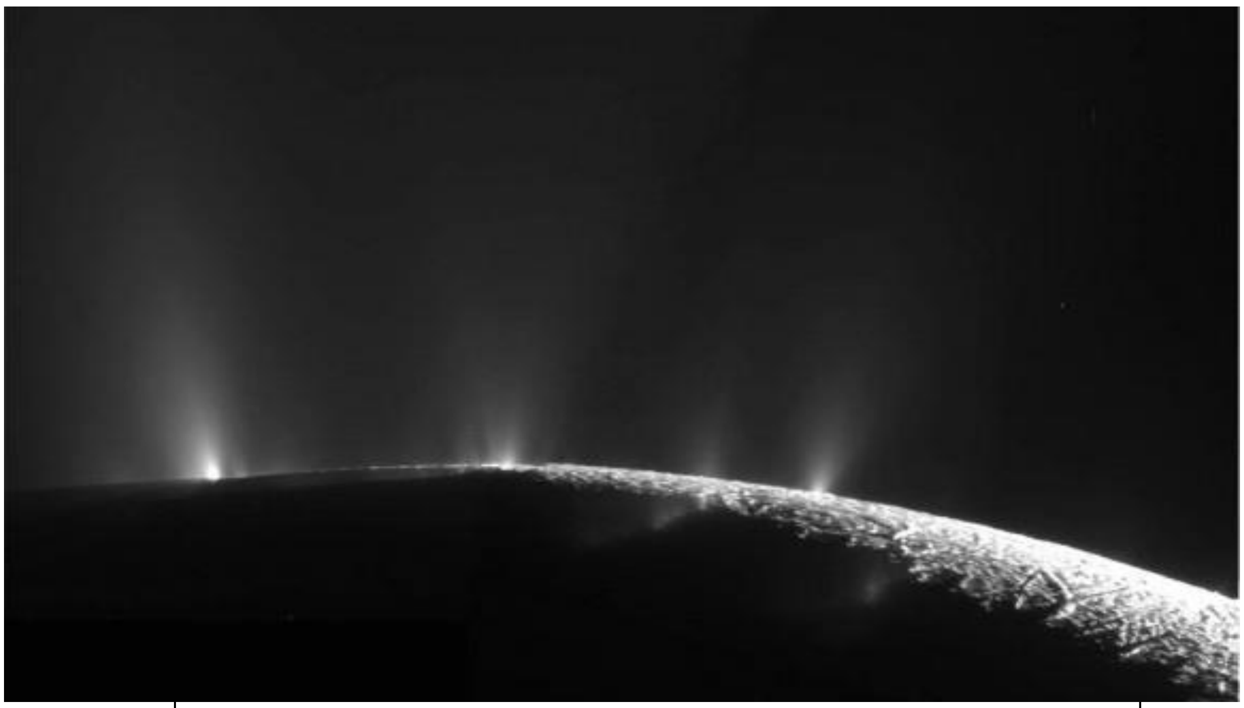
Enceladus is extremely bright, owing to the shell of ice encasing the moon that reflects almost 100% of sunlight to produce the crystal white color of the surface. Due to this reflection, the surface absorbs only a small amount of radiation and is consequently extremely cold, at around -201°C. Parts of the surface are covered in meteor craters, but some areas are completely free of such impacts. This suggests that the surface is shifting, which would lend support to the theories about the internal composition of the moon. But, if the moon reflects almost all light and we have no landers or drilling equipment, how can we possibly determine the interior structure? The answer, interestingly, is that Enceladus *wobbles.* By calculation, scientists have determined that the minute but detectable movement in its orbit is consistent with a model where the interior of the moon is not solid but liquid. Given the composition of the surface and of the geyser material, it is logical to suggest that Enceladus contains a vast underground ocean that feeds these geysers.

Continued on the following page…

Enceladus cont.

So, if the surface sits at roughly -200ºC, why does the underground ocean not freeze entirely? This is one of the trickiest questions to answer, since we simply do not have enough data on the composition of Enceladus to provide an accurate theory. However, the prevailing hypothesis is *tidal heating.* Essentially, the gravitational field of Enceladus interacts with that of another moon, Dione, which pulls Enceladus into a more eccentric (oval shaped) orbit than would be normal. We mentioned earlier that the liquid interior of the moon 'sloshes' around slightly during this orbit, and as it moves it resists the force pulling the moon into the more eccentric orbit – it acts as a damping mechanism. As with any other damping mechanism, energy must be converted from the kinetic to some other form, and it is hypothesized that this damping effect heats the interior of the moon, thus keeping the ocean liquid. This is somewhat of a self-fulfilling prophecy in that the interior is liquid because of the heating caused by the effect of a liquid interior, but this model nonetheless agrees with our current measurements.

An underground ocean naturally encourages questions about the possibility of extraterrestrial life. Enceladus possesses an ocean of liquid water, a source of heat and evidence of basic organic compounds, so the possibility is less remote than might be initially assumed for an icy world far out in the solar system. Indeed, it is one of the most promising bodies in the search for life beyond our own blue marble – so the first aliens we find might not be Martians but Enceladians.



Geysers of Water Vapor Erupting at the South Pole of Enceladus by NASA/JPL

Beginner's Guide: Eclipses

By James Li

For many people, the most significant recent astronomical event was probably the solar eclipse back in August. There are actually several kinds of solar eclipses, like the partial eclipse seen from Atlanta, and a total eclipse in other parts of the US. It's only a total eclipse when the Moon completely covers the Sun, but some people may wonder why don't we see an eclipse every month during the new Moon?

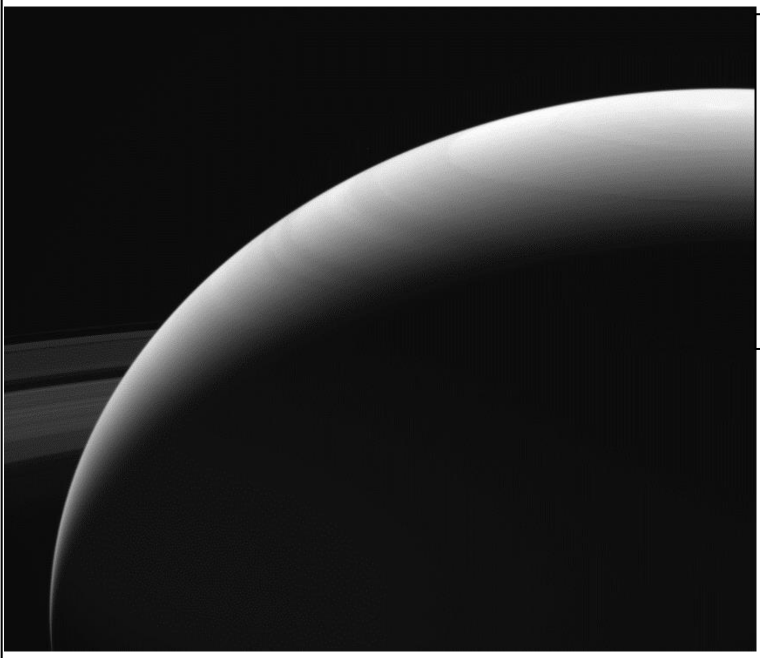
The answer to that is that since the Moon does not have a perfect orbit. It's actually inclined slightly, meaning it'll sometimes be above or below where the Sun is in the sky, so no eclipse. On top of that, the Moon's orbit is elliptical, meaning its distance from Earth changes, by as much as 26,000 miles.

Although the elliptical orbit doesn't affect when an eclipse happens, it sometimes causes an annular eclipse, where the Moon looks slightly smaller than the Sun from Earth and can't completely block it out.

If you had a chance to see the total eclipse, then you saw a wispy halo around the Moon. This part is the chromosphere and corona, which sit on top of the surface, called the photosphere. The chromosphere is relatively small and a bit colder than the photosphere (7000 F vs 10000 F) so it looks reddish. The corona extends out very far and has really hot particles at millions of degrees. We aren't sure why this part is so hot, but we think it's because of the Sun's magnetic field.

Photos of the Month

The above photo was taken by student photographer Haoyu Xiong during the total solar eclipse of August 21, 2017. This is not a single image, but actually a combination of 10 different photos using HDR post-processing to make it possible to see the inner corona, outer corona, solar prominences, and the dark side of the Moon all in the same picture. Image credit goes to Richard Xiong, an electrical engineering student at



Saturn: Before the Plunge by NASA/JPL

This is one of the last photos taken by the Cassini space probe on September 13, 2017 before it was destroyed in Saturn's Atmosphere

Astronomical Events Calendar

- October 19: New Moon – This is the best time of the month to see faint objects because of the lack of moonlight
- October 19: Uranus will be at its closest approach to Earth. The Sun will fully illuminate Uranus, making it the brightest that the faint planet will be all year.
- October 21-22: Orionids Meteor Shower - Best viewing will be a dark location after midnight. Meteors should pass through the sky with an average quantity of about 20 meteors per hour.
- October 26: GT Observatory Public Night at the Howey Physics Building
- November 4: Full Moon
- November 4-5: Taurids Meteor Shower – A smaller meteor shower producing only about 5 to 10 meteors per hour. It will mostly be blocked out by the brightness of the Full Moon, but some meteors will still be visible in dark locations away from cities.