The Jewel of the Solar System:

The Rings

Submitted By: Maria Vina Quiambao

Student Number: 500523481

Instructor: Dr. Dave Kirsh

Course Code: CPCS 581

Date: November 10, 2016

The Planet Saturn

Saturn is the sixth planet from the Sun, and the second largest in the Solar System.[5] It is a gas giant composed of mainly hydrogen and helium with an average density of 0.69 g/cm^3, making it the least dense of all the planets in the Solar System and even less dense than water. While Earth's terrestrial clouds produce water droplets, Saturn's clouds precipitate droplets of liquid helium. These helium droplets meet resistance as they fall through the the planet's atmosphere, allowing them to radiate heat throughout Saturn by kinetic energy.[5] According to astronomers, helium rains may cause Saturn's temperatures to rise to 5,500ºC below its atmosphere, even though the outermost atmosphere remains at a cool minus 185ºC.[1] So far astronomers have confirmed 53 moons that orbit the planet, each bearing their own unique stories.[2] Titan, for example, may be hiding an ocean just beneath its surface which have astronomers claiming that this moon can potentially hold the ingredients for life. Clearly, Saturn's system is bursting with science. As if these facts alone are not enough to be intrigued by Saturn, they have not even touched on the iconic rings that give Saturn the name, "the Jewel of the Solar System". What exactly are the rings made of? Why do they shine so brightly? How were they formed in the first place? Jupiter, Neptune, and Uranus all have rings,[8] but why are Saturn's rings so much more grandiose? Due to the complexities behind the existence of Saturn's rings, this report will focus on unfolding the science behind how we understand those glorious rings today.

The Early Saturn

Today, Saturn may be known for its rings, but during its early days of discovery, the rings were more of a mystery than distinguishable rings. Galileo Galilei was the first to identify

Saturn in the year 1610, except, due to the early telescope's poor resolution, he perceived Saturn and its rings as three separate bodies. Image 1 shows how Galileo sketched the planet as one main body surrounded by one 'companion' on each side.[3] The year after, he was baffled at how the two 'companions' had completely disappeared, but then returned again in 1616 in the shape of 'handles', as shown in Image 2.[3] For years, early astronomers attempted to determine what these 'handles' were and why they changed overtime.

Image 1: Galileo Galilei's sketch of Saturn and its 'companions', as he observed the planet in 1610.[3]

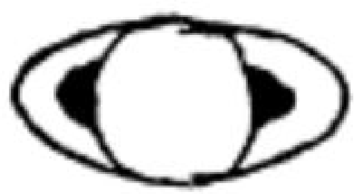

Image 2: Galileo Galilei's sketch of Saturn and its 'handles', as he observed the planet again in 1616.[3]

Identifying the Disappearing Ring

With a more powerful telescope than Galileo's in 1659, Christiaan Huygens became the first to suggest that those 'companions' or 'handles' are actually a flat, solid ring encircling the planet. Though not entirely correct, Huygens had another assumption to build on this idea. In his book, *Systema Saturnium*, Huygens also proposed that the evolving images of Saturn were actually caused by the planet's tilted rotational axis. In Image 3, he shows how Earth's view of the rings depends on Saturn's position.[3] The entire ring system is 282,000 kilometres wide from one outer edge to the other,[1] and measures to an average of only 10 metres in thickness.[2] This is paper-thin compared to the size of Saturn itself, which has a surface area of 83 times that of the Earth.[2] The thinness combined with Saturn's tilt of 26.7 degrees together create the illusion of disappearing rings when they are seen edge on from Earth, which is also known as ring plane crossing. Ring plane crossings occur once every 14-15 Earth years - in between, giving Earth different views of Saturn's rings - explaining Galileo's bafflement of the disappearing 'handles' and confirming Huygen's assumption about Saturn's changing images.[6]

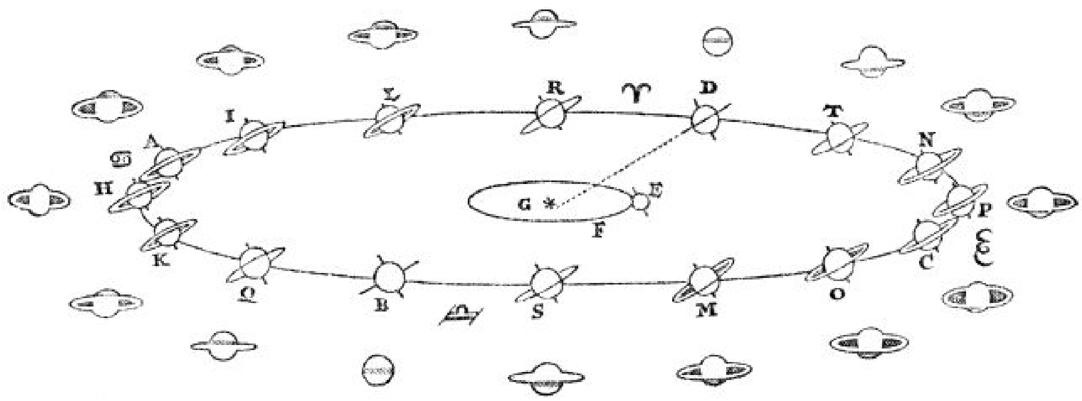

Image 3: Huygens' illustration on how Saturn's image evolves overtime and how ring plane crossing occurs, as shown in his book, *Systema Saturnium*.

Identifying Multiple Rings

During the year 1675, Giovanni-Domenico Cassini built on Huygen's idea of the solid ring when he discovered a division within the ring, suggesting that there is not one, but two distinct rings surrounding Saturn. This division is now known as the Cassini division, which is 4,700 kilometres wide, making it the widest gap within Saturn's ring system to date.[2] Image 4 illustrates how this gap separates one ring from the other.[12] Gaps between the rings, such as the Cassini division, have allowed astronomers to identify seven distinct rings surrounding Saturn so far. They are called A, B, C, D, E, F, and G, respectively named after the order of their discovery from first to last. Each ring varies in size and brightness: A, B, and C are the widest and most visible rings, while D, E, F, and G are more narrow and faint.[2] This then leads us to the next question: Are these rings actually solid? But either way, what in the world are they made of?

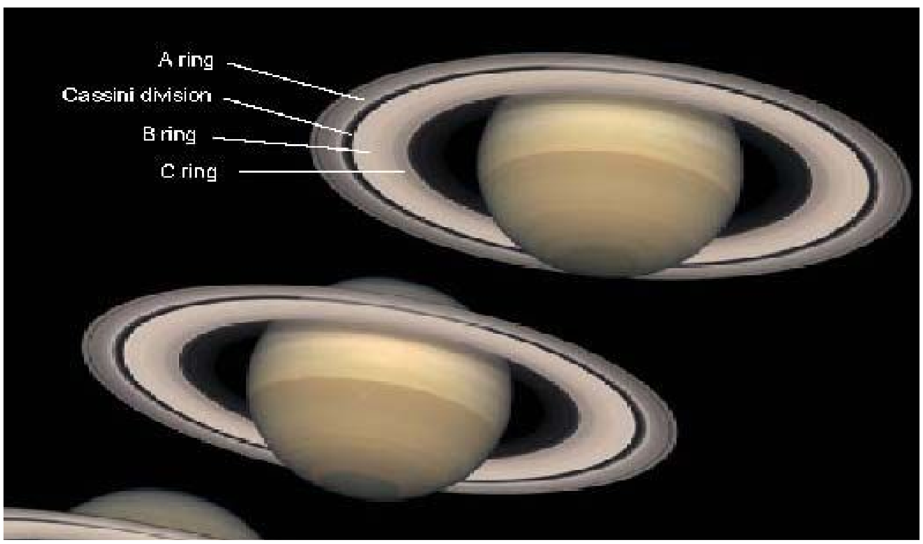

Image 4: As labelled on this image provided by *Hubble Heritage*, the wide Cassini division clearly separates the A ring and the B ring.[12]

Identifying Orbiting Particles

More than 180 years later, James Clerk Maxwell mathematically proved that the rings, in fact, could not be solid. He proposed that since a solid planetary disk would become too unstable and tear itself apart, smaller orbiting particles must be responsible for giving the illusion of solid rings.[5] He was right. Today, we understand that the ring system is composed of billions of chunks - some are as small as dust while others are as large as mountains.[2] According to Brian Cox, each of them orbit Saturn independently at different speeds of up to 80,000 kilometres per hour.[9] In accordance with Kepler's Law, the chunks closest to Saturn orbit faster than those that orbit along the outer edges of the ring system.[10] These chunks are made of 90-95% water ice and easily reflect light from the Sun, making the rings vibrant and clearly visible all the way from Earth. In comparison, Jupiter's rings have more rock content, therefore, its rings are difficult to see and cannot create the same illusion of bright and solid rings from afar.[7] Cox further explains that the reason why the ice chunks shine as if they were new is because they constantly collide with one another. After each collision, they shatter and expose new pieces of ice which brilliantly recapture the Sun's light.[9]

What keep these fast-moving, colliding ice chunks within their distinct paths are Saturn's moons. The moons that orbit in between or within close proximity of the ring system serve two purposes: creating the gaps between the rings, and maintaining the strict orbital paths which the ice chunks follow. For instance, astronomers say that the Mimas moon caused the wide Cassini division and continues to sweep the particles clean out of the gap through gravitational resonance,[5] while Prometheus and Pandora act as "shepherd moons" near the outer rings as they "herd" straying ice back into orbit through their gravitational pull.[1] Image 5 is a photo of Pandora herding the F ring from the outer edge while Prometheus herds the F ring from the inside.[11] Some of the moons have also created gaps within the main rings. For example, Image 6 shows how Pan created a division within the A ring to form the Encke gap.[12] For these reasons, Saturn's moons are key players in maintaining the ring system's structure and its delicate shape.

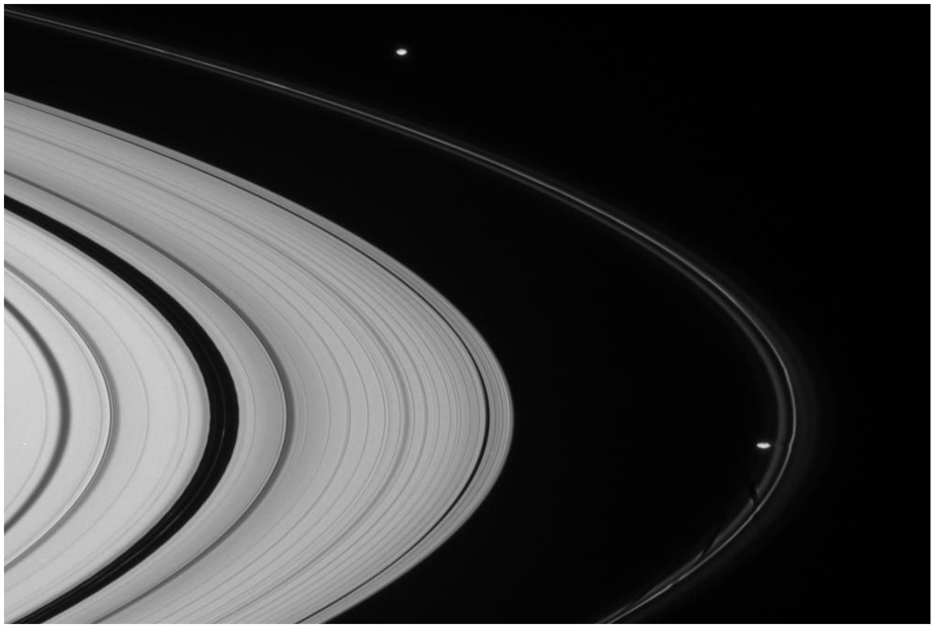

Image 5: Shepherd moons, Pandora and Prometheus, are seen herding the ice particles furthest from the planet to maintain the F ring.[11]

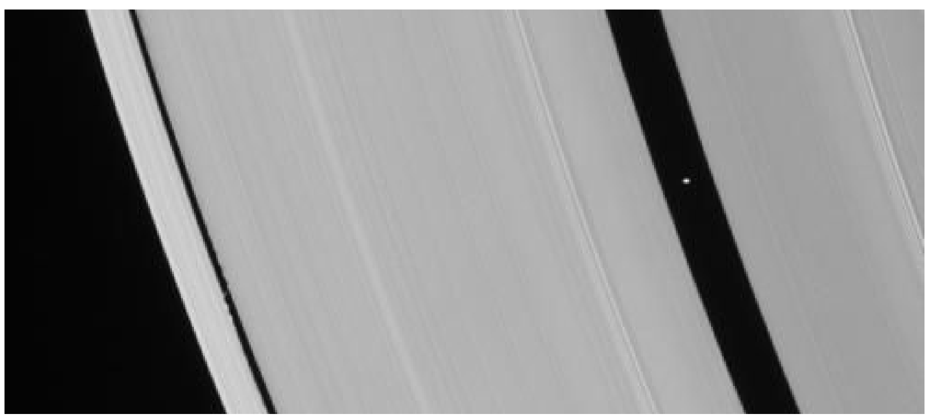

Image 6: With a closer view of the A ring, Pan is seen causing the Encke gap within the ring itself.[12]

Theories on Ring Formation

Since the early days, astronomers have debated over the origins of Saturn's rings. One of the many suggestions is that two of the planet's moons may have crashed into each other, and

Saturn's gravity pulled the collision's shards into orbit to create the rings we see today. Another argument is that instead of two of the moons, the collision may have involved one moon and a large fast-moving object.[10] One of the more recent ones, introduced on September 2016, proposes that it may be the Late Heavy Bombardment which caused the rings on Saturn to appear - even the rings on Jupiter, Uranus, and Neptune. According to Hyodo et. al, the Kuiper Belt may have contained more objects than observed today, and at one point, some of those objects may have scattered throughout the Solar System, affecting all the planets within. It is likely that the objects that may have approached Jupiter's, Uranus', or Neptune's Roche Limit, were entirely tidally destroyed and then pulled into orbit by the planet's gravity. However, in Saturn's case, it is possible that when the object reached the planet's Roche Limit, only the ice particles were torn away and pulled into orbit by gravity while its rocky core was able to escape. The objects that approached each planet may have been composed of different materials, which may explain why Saturn's orbiting particles are made of water ice and much less rock, unlike the other planets. Hyodo and his team created a simulation to test what would happen if this scenario was true. The simulation indicated that the chunks that were tidally destroyed and put into orbit likely would have started out as large pieces, but overtime collided with one another over and over again, resulting in smaller orbiting objects. This may explain why Saturn's ice chunks vary greatly in size.[8] But, of course, this is only one of the many possibilities regarding the rings' origins. Perhaps the Cassini orbiter, launched into space almost 20 years ago, may reveal information that will solve the mysterious origins of Saturn's rings.

On October 15th, 1997, the Cassini orbiter began its billion mile journey to Saturn to observe the planet's nature as never been seen before. Since then, the orbiter has discovered rich information about the Saturn system - a few of which include two new moons, lakes on Titan, gas compositions throughout the system, and fainter rings around the planet that were never seen before. Fast forwarding to today, the Cassini mission will soon be entering its last phase, “The Grand Finale”, which will take a closer look at Saturn’s rings. On November 30th, 2016, the orbiter will make its way to Saturn’s north pole, and by April 22nd of 2017, it will fly south in between Saturn and its innermost rings. This gives the orbiter a chance to have a detailed view of Saturn’s atmosphere and the rings. The Cassini mission team is confident that this last phase will bring astronomers closer to understanding the rings system’s origins.[11] Perhaps, they will also find clues regarding the future of the rings.

Theories on the Future of the Rings

Will the rings last forever, or will they eventually disappear? Due to the recurring collisions happening among the ice particles, some astronomers believe that the particles may shatter in such small pieces that the particles may obtain a charge and eventually be swept away by Saturn’s magnetic field. Another assumption is that the rings may simply spiral into the planet overtime. It is believed that in order for the rings to stay intact, the material within the ring system must be replenished. For instance, a comet crashing into the rings may be what Saturn needs to preserve its rings.[10] However, even with deep speculation, astronomers are still uncertain about the future of the rings since the ring system’s origins are still in debate. In the meantime, the world waits as Cassini enters “The Grand Finale”, which may very well give astronomers the key to unlock both the past and the future of Saturn’s most iconic rings.

Reference List

1. Kerrod, Robin. *Saturn*. Minneapolis, Minn: Lerner Publications Co, 2000. *eBook Collection (EBSCOhost).*
2. B. Dunford. “Planets: Saturn”. NASA. Retrieved from http://solarsystem.nasa.gov/planets/saturn/
3. A. Van Helden. *Huygens, Titan, and Saturn's ring. In:* Proceedings of the International Conference "Titan - from discovery to encounter", 13-17 April 2004, ESTEC, Noordwijk, Netherlands. Ed.: Karen Fletcher. ESA SP-1278, Noordwijk, Netherlands: ESA Publications Division, ISBN 92-9092-997-9, 2004, p. 11 - 29, Retrieved from http://articles.adsabs.harvard.edu//full/2004ESASP1278...11V/0000012.000.html
4. National Geographic. “Saturn: The Ringed Planet”. Retrieved from http://science.nationalgeographic.com/science/space/solar-system/saturn-article/
5. M. Beech. "Saturn." *The Gale Encyclopedia of Science*. Ed. K. Lee Lerner and Brenda Wilmoth Lerner. 3rd ed. Vol. 5. Detroit: Gale, 2004. 3513-3518. *Gale Virtual Reference Library*. Web. 7 Nov. 2016.
6. T. Phillips. “The Vanishing Rings of Saturn”. *NASA*. Retrieved from https://science.nasa.gov/science-news/science-at-nasa/2008/18mar_saturn/
7. D. M. Harland. *Space Exploration: Cassini at Saturn: Huygens Results*. New York, NY, US: Praxis, 2007. ProQuest ebrary. Web.
8. R. Hyodo, S. Charnoz, K. Ohtsuki, and H. Genda. *Ring Formation Around Giant Tidal Disruption of a Single Passing Large Kuiper Belt Object.* Paris, France: September 2016. Retrieved from https://arxiv.org/pdf/1609.02396.pdf

9. B. Cox. *Wonders of the Solar System*. BBC. Documentary Series. 2010.
10. National Geographic Space. Saturn: Lord of the Rings. Documentary Series. 2015.
11. B. Dunford, E. Piazza, J. R. Thompson. Cassini Mission to Saturn. Jet Propulsion Laboratory. 2016. Retrieved from https://saturn.jpl.nasa.gov/
12. D. G. Simpson. The Rings of Saturn. *NASA Goddard Space Flight Center.* Retrieved from http://caps.gsfc.nasa.gov/simpson/kingswood/rings/