Theories on how the moon was formed

Earth’s sole natural satellite was first scientifically observed through Galileo Galilei’s telescope since 1610. The celestial body Galileo was observing makes a complete orbit around Earth in 27 earth days at a distance of 384 thousand km [1] . The Moon rotates and spins at the same rate which causes it to keep the same side or face towards Earth during the course of its orbit [1] . The satellite moderates the Earth’s wobble on its axis through a gravitational pull which is responsible for stabilizing the weather, and also for creating a tidal rhythm that has been helping humans for thousands of years. The Moon is also responsible for helping nocturnal animals see at night through its light reflecting from the Sun onto the Earth. Earth’s moon is a rocky solid body containing a cratered surface from impacts, with an exosphere (a very thin and weak atmosphere) and lack of liquid on its surface that cannot support life [1] . Although this celestial body cannot support life, it has helped life on Earth since the beginning. How was the moon created? There are several lunar origin theories which will be explained further in this paper.

There were three pre-Apollo major theories that have been speculated for centuries [2] . These are: capture theory, fission theory, and the double planet theory [3] . The fission hypothesis was proposed by Charles Darwin’s son, George Darwin in 1878. He thought that the Moon and the Earth were a part of each other [2] and that the Earth had been spinning so fast that material broke off from the Earth which formed into the Moon. The reason why he thought this was because of Kepler’s third law, and also because of his observation that the Moon’s orbital period was growing around the Earth suggesting that it must have been closer to Earth at one point. Kepler’s harmonic law relates the orbital period of a planet to its average distance

from the sun showing that closer planets travel at greater speeds and also have shorter orbital periods [4] . This was a popular theory for the longest time even though it had its problems. Another scientist, Osmond Fisher, encouraged the idea and thought that the Pacific Ocean was actually a scar left from the separation of the Earth and the Moon [2] . This theory was eventually disproved and later on, researchers showed that in order for the Moon to separate from the Earth, the Earth must have been spinning so fast that it was rotating around the sun at least once every two and a half hours [3] which scientists believe couldn't have happened. Also, a scientist named Forest Ray Moulton showed through mathematics of the stability of fluid mechanics, the Moon could not have been formed through fission [2] .

The second major theory that was hypothesized was the co accretion theory, double planet hypothesis, or the condensation theory. This theory suggests that the Moon and Earth formed together at the same time by co-accretion through the original Nebula that formed the solar system (suggested by Pierre-Simon Laplace) [2] . This theory is observed through binary star systems and has the greatest astronomical observational support. It also has the help of the Roche limit proposed by Edouard Roche that shows the physical limit to how close the Moon can be as a celestial body disproving the fission theory as well. This limit showed that the Moon could only have existed as a ring of debris similar to Saturn and Jupiter [2] . Unfortunately, problems were observed with this theory since scientists could not explain why Venus did not have a moon, and why the Earth did not share the same properties as

the Moon such as the type of core each had (Earth is dense, the Moon is not), a differing gravity force, and the amount of Iron each body had [3] .

The third pre-Apollo major theory that was proposed was formulated by Thomas JJ See. He suggested that the Moon was a captured satellite and that it was actually formed further out in the solar system as far as Neptune [2] , and somehow, the Moon became close enough to the Earth that the gravitational pull of the Earth captured it. This theory could explain why the Moon and Earth do not share the same properties and is also evident in the universe itself with Mars and other planets. However, this too had its problems because it is very unlikely that a celestial body with the Moon's shape and elliptical orbit could have found the Earth the way it did. If it was slightly different (which it should have been), it would have crashed into Earth or would have been thrown away from it [3] .

After the Apollo 11 lunar landing with the first men on the Moon, there was a new hypothesis generated through the help of a little piece of moon rock. The moon rock showed that volatile substances with low boiling points such as water were rare as well as metals such as potassium and sodium [3] . This in itself discredited the fission and double planet theories because if these were true, the Moon would have the same composition as the Earth. The latest theory is also known as the canonical moon theory: the Giant Impact Hypothesis [3] . It in a way combines all three theories to form one that makes the most sense overall. This hypothesis proposes that the Earth was struck by another celestial body the size of Mars called Theia [5] (capture hypothesis). The impact of this collusion expelled large amounts of material

(the fission hypothesis) [2] , and since Theia had a less dense mantle, Earth's core was untouched by the impact [5] . The material which was a ring of very hot debris [6] eventually coalesced or condensed into Earth's sole satellite (co-accretion hypothesis) [2] . This also implies that the Moon would have formed very hot or possibly molten which also disapproves that the Moon was formed solely through the capture hypothesis since if the moon was captured it would not heat up as much as it did. Moreover, the substances on the Moon are more common to silicon and aluminum which are substances with high boiling points [3] .

Although the Giant Impact Hypothesis is what most scientists believe to be the origin of the Moon, there has been new research by geochemist Junjun Zhang from the University of Chicago that looked at titanium isotopes, t [50] to t [47] in 24 separate samples of moon soil and rock [5] . The geochemist tested titanium since Theia should have left its signature on the Moon after the giant collision and it is very unlikely that Earth could have exchanged titanium since it has a very high boiling point [5] . However, research showed that similar to oxygen isotopes from previous research, titanium shares a good proportion of the Earth's mantle [7] . This is troubling since Theia was thought to be a ways away from the Earth. Moreover, Robin Canup from the Southwest Research Institute in Boulder, Colorado shares input and states that oxygen isotope composition of Mars differs from Earth by a factor of 50 so it is improbable for the Moon to have the same proportions of oxygen and titanium [7] . Another study was conducted in 2012 by Matija Cuk from SETI (Search for Extraterrestial Intelligence) and Sarah Stewart from Harvard

University [7] and suggests that if the Earth was spinning faster than it is now (to have two or three hours for a day), the planet could have thrown enough material to form the Moon. After forming the Moon, the gravitational pull could have eventually slowed down the Earth's spin rate eventually producing the 24 hour day we have today [7] .

In order to understand how the universe works, more research needs to be conducted including a mission to Venus [7] so that we can better understand how and why the Earth and Moon have the composition they do. We already know the composition of Mars so it is important to know how the other planet beside us, Venus, operates as well. Although we have theories of how the Moon was formed, even the canonical Giant Impact Hypothesis seems to be wrong due to recent research about the Earth and Moon's properties. I think it is very likely that Matija Cuk and Sarah Stewart's hypothesis is correct, that is, the young Earth may have spun fast enough to form a moon. The Earth could have been closer to the Sun than it is today which is highly probable due to the dark energy slowly expanding our universe. Moreover, the debris may have shaped into the Moon's form, a spherical satellite, which can be observed through an example of binary star systems. Eventually, the Moon could have been big enough to stabilize the Earth's orbit, to conduct how long our days are today, and further support life on Earth by providing ocean tides to influence the Earth's climate.