GALILEO PROJECT

PHY 2900U

Group 18

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Introduction

Approximately 400 years ago, Galileo Galilei had revolutionized astronomy with the use of telescopes to look up into the heavens. Around the years of 1609, he in fact had improved the basic modelling of telescopes and made discoveries that challenged the original geocentric model of the universe. His findings included the Galilean Moons, which are four moons which orbit Jupiter – Io, Europa, Ganymede, as well as Callisto – which provided solid evidence that not every celestial body orbited the earth. He later also discovered the phases of Venus, which demonstrated and was further proof that Venus orbits the Sun and not the Earth. These discoveries rather supported Copernicus's heliocentric model.

Galileo also further discovered many properties of our local Moon. He noted mountains and craters, contradicting the popular belief that celestial bodies are perfect spheres as the belief followed that the heavens were perfect. His observations of sunspots also showed that even the Sun was not immutable. Lastly, he also revealed that the Milky Way consisted of countless stars, which expanded our premise of the known universe.

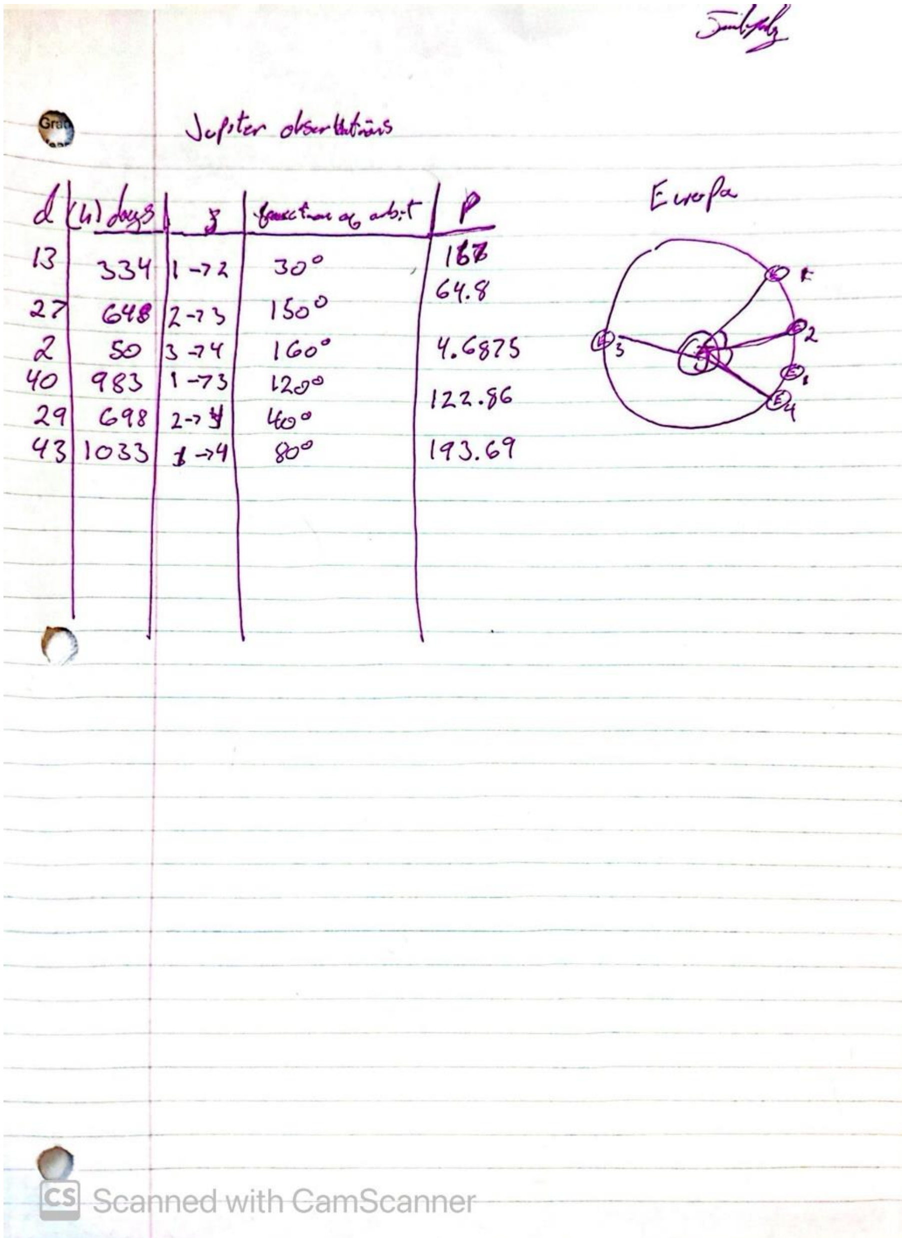
These observations were extremely significant in changing the perspective and belief of the universe being Geocentric. This was a model in which society had full faith that our planet, Earth, was at the center of the universe and instead he proved a Heliocentric Model. Galileo essentially established the groundwork of modern astronomy by providing empirical evidence and observations which challenged the beliefs at the time.

Motivated by Galileo's past pioneering work, our group was heavily influenced and inspired to have our own observations of certain celestial objects that he once viewed. Utilizing modern refracting telescopes which mimic Galilean telescopes, we examined Jupiter, Saturn, our Moon as well as the M31 Andromeda Galaxy. While Galileo did work with narrow field of views, and small magnifications with his telescopes, using the same type of telescope today allowed us to further appreciate his discoveries. It gave us more insight and further appreciation for his contributions with the tools he once used. The following observations reaffirm the significant impact of Galileo's work and highlight his progress in our understanding of the universe.

Observations

Jupiter - Appendix A: Jupiter Observations

Based on our observations of Jupiter, we carefully tracked the positions of its major moons over time, providing a clear demonstration of orbital motion around the planet. To calculate the period of the moons of Jupiter the method that we were using was to find the change in time between days of observations and the degree of separation between the moon's images. Ultimately, after doing the calculations I think due to human error there are a lot of inaccuracies. One possibility that I have considered is that because the accepted orbit of Jupiter's moons are very short and our observational data were very spaced out the observations ended up being very close to each other in the moon's phases resulting in a very small dataset to work with. This limitation made it challenging to accurately calculate the orbital periods with high precision. Despite these inaccuracies, the general trend of orbital motion was still evident, providing strong support for the heliocentric model and the concept of gravitationally bound systems.



Jupiter observations

d	(h) days	?	fraction of orbit	P
13	334	1 → 2	30°	167
27	648	2 → 3	150°	64.8
2	50	3 → 4	160°	4.6875
40	983	1 → 3	120°	122.86
29	698	2 → 4	40°	
43	1033	1 → 4	80°	193.69

Moon – Appendix B: Moon Observations

During our group's moon observations, we were able to obtain 5 different observations on different dates to get a better understanding of the moon's phases and how Galileo would have used them push the concept of a helio-centric model of the universe. For a brief overview of each observation along with their phase of the moon see table 2 below. Our first observation was on October 19^{th} and was in the Waning Gibbous phase. Some of the key features we were able to observe during this day were the large craters on the front face of the moon as well as slightly above as well as the identifiable covering of the right side of the moon. November 1^{st} was the second observation and took place while the moon was in a New Moon phase. Because the moon was in a new moon phase the visibility was extremely low and practically invisible. The third observation was on November 12^{th} and was during a Waxing Gibbous. During this observation we can again get a glimpse of the craters and identifiable terrain on the face of the moon. The fourth observation on November 23^{rd} was another Waning Gibbous and our last observation was a Waning Crescent on November 26^{th} where most of the moon was shadowed in darkness.

Based on our findings we can see that, just like Galileo observed, the moon is a perfect demonstration of how astronomical bodies orbit around large gravitational bodies. This helps illustrate the concept of the helio-centric model of the universe because the phases of the moon demonstrate how an object will appear when orbiting around another object. In Galileo's day he used the phases of Venus to show that the planet was orbiting around the sun despite remaining near to the sun in the Earth's sky, proving that not everything is orbiting around the Earth. Without the knowledge of how phases work and look like obtained from watching the phases of the moon, this discovery may not have been possible. With our observed data we have calculated the period of phases of the moon to be roughly 33 days. When comparing this to the actual established value of 29.5 days we result in an error percentage of 13%. This is higher than we would like but is still a great example of how early astronomers such as Galileo would have been able to discover this groundbreaking information in the world of astronomy.

Table 1	Change in days
Oct19th – Nov 1st	14
Nov 1st – Nov 12th	12
Nov 12th – Nov 23rd	12
Nov 23rd – Nov 26th	4

Table 2	Phase
Oct19th	Waning Gibbous
Nov 1st	New Moon
Nov 12th	Waxing Gibbous
Nov 23rd	Waning Gibbous
Nov 26th	Waning Crescent

Table 3	Fraction of a cycle
Oct19th – Nov 1st	3/8
Nov 1st – Nov 12th	3/8
Nov 12th – Nov 23rd	2/8
Nov 23rd – Nov 26th	2/8

Table 4	Period of a Cycle of Phases
Oct19th – Nov 1st	37.333
Nov 1st – Nov 12th	32
Nov 12th – Nov 23rd	48
Nov 23rd – Nov 26th	16
Average Period	33.33325

Calculation:

Period of a cycle of phases = $\frac{\Delta Time}{Fraction\ of\ a\ cycle} = \frac{14\ days}{\frac{3}{8}} = 37.333\ days$

Average period = $\frac{\Sigma P_i}{\#\ of\ data\ points} = \frac{(37.33 + 32 + 48 + 16)}{4} = 33.33325$

Percent Error = $\left|\frac{(Experimental - Theoretical)}{Theoretical}\right| \times 100\ = \ \left|\frac{(33.33325 - 29.5)}{29.5}\right| \times 100\ = 12.994\%$

Saturn - Appendix C: Saturn Observations

Based on our observations of Saturn, the rings appeared to maintain a consistent angle of orientation as there was no showing of significant changes between our recorded dates (October 28 – Nov 2) Using the sketches made during these observations, we estimated angle of the rings relative to edge-on by measuring the tilt of the ring structure in relation to the horizontal axis of the image. To do this, the group aligned a protractor or visual estimation tool with the major axis of the ellipse formed by the rings. From my sketches, the tilt seems to be approximately 20°–30° from edge-on.

We did not notice a substantial difference in the ring angle between the two dates. This is likely due to Saturn's slow orbital motion and the short time interval between my observations. The planet's axial tilt and the position of Earth in relation to Saturn during this period make it difficult to perceive noticeable changes in the ring orientation over just a few days. We have concluded that a longer observation period would be necessary to observe any significant change in the angle of Saturn’s rings.

Extra Celestial Body M31 Andromeda - Appendix D: M31 Andromeda Observations

For both observations, the M31 Andromeda Galaxy appeared as a patch of light in the sky with neighbouring stars surrounding it. The difference between the first and second observation was the position in the sky. The galaxy appeared higher in the sky at 85 degrees altitude almost directly north with 357 degrees in direction compared to the first observation. The differences in altitude and direction mean the galaxy shifted due to our rotation and orbital position.

The M31 Andromeda galaxy is 2.537 million light-years from us. It is the closest galaxy to our own in the Milky Way. Observing Andromeda with the naked eye it appears to be very faintly visible. Almost like a blurry patch of light, but without the telescope it's hard to spot and be certain. As for observing through the telescope, the center becomes brighter, and it is a lot more detailed than with the naked eye, but it still appears as a blurry cloud surrounded by its neighbouring stars.

Discussion

Through our observations of Jupiter, Saturn, the Moon and the M31 Andromeda Galaxy, our group has gained a deeper understanding of the role of these celestial bodies challenging the idea of a geocentric model of the universe. Every one of these observations highlighted a pattern that aligned more closely to a heliocentric model.

Jupiter and its moons provided essentially the most significant evidence against a geocentric universe as it did when Galileo discovered them. Even with the inaccuracies we had, these were objects orbiting around an entirely different planet which reinstates that not all bodies orbit the earth. Our groups observations had noted shifts of Jupiter’s moons which exhibited their orbiting traits and supported the idea of gravitational orbits rather than just orbiting the Earth.

The Moon’s phases further support the heliocentric model as well. As the moon orbits the Earth, its phases change due to the angles of sunlight that hit it and reflect. The moon’s cycle demonstrates the relationship between the Moon, Earth and Sun and it defies the idea that everything orbits the Earth. In fact, similarly Galileo had also discovered the phases of Venus and derived the same counterargument.

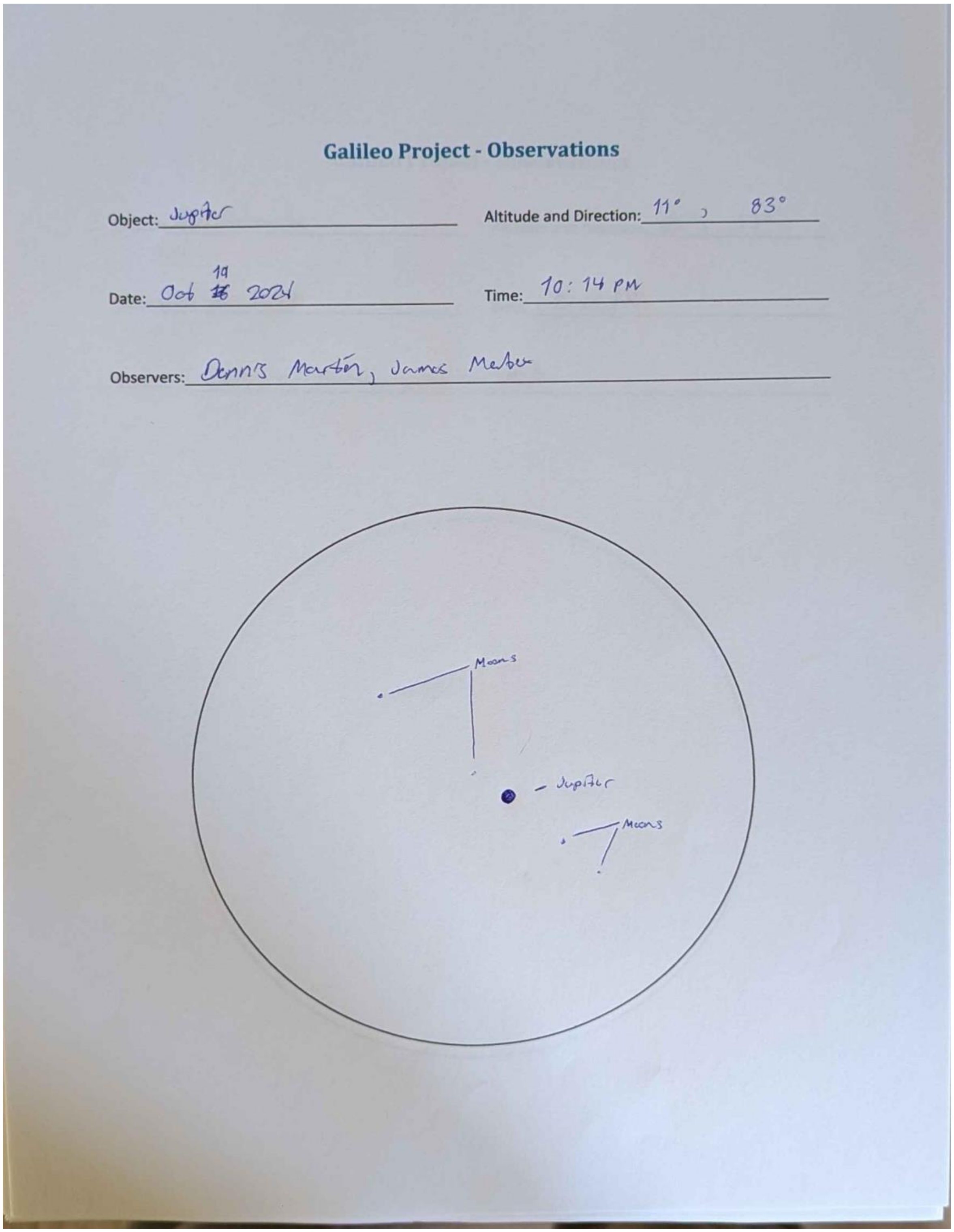
The observations of Saturn, although less groundbreaking than the previous two, still lead to believe a heliocentric model. There was no significant change in the angle of its rings, yet the consistent tilt and orientation affirm the ideas and principles behind axial tilt. This observation, although somewhat neutral still enforces the dynamics of our Solar System.

Lastly, the slight observations of M31 Andromeda had given significant reason to believe that there is a universe which stretches far wider than just our Solar System. The faint patches our group found still gives us a good idea that other galaxies exist in which Earth is anything but at the center of it. The galaxy’s position changing due to Earths rotation and orbit shows that we our just as dynamic, and not just fixed at a place while everything moves around us.

In conclusion of this report, we are deepened in our appreciation for Galileo’s work. His observations were far from the common belief at the time, and it is extremely difficult to prove such ‘backwards’ ideas without sufficient proof. Finding that proof takes a lot of work and dedication with keen attention to detail. These observations have provided us with a deeper insight into the foundational groundwork that was laid out to what we have in the field of astronomy today.

Appendix

Appendix A: Jupiter Observations



Galileo Project - Observations

Object: Jupiter

Altitude and Direction: 11° , 83°

Date: Oct ~~16~~ 19 2024

Time: 10: 14 PM

Observers: Dennis Martin, James Meber

Galileo Project - Observations

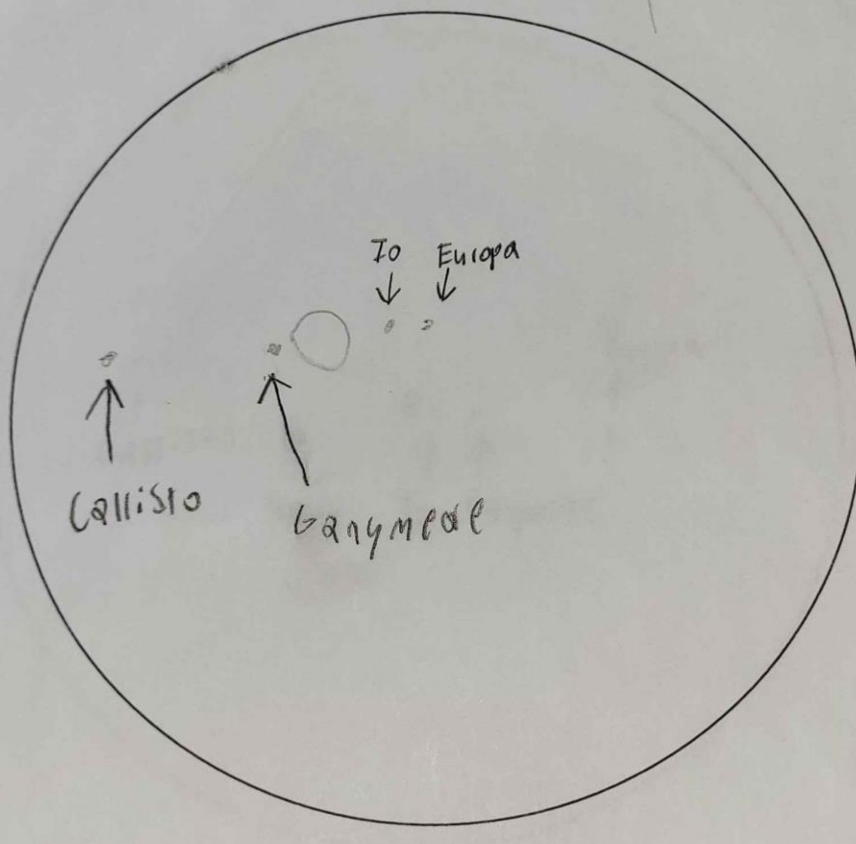
Object: Jupiter

Altitude and Direction: 11°, 83°

Date: Oct 19th 2024

Time: 10:13 pm

Observers: James Dennis



Galileo Project - Observations

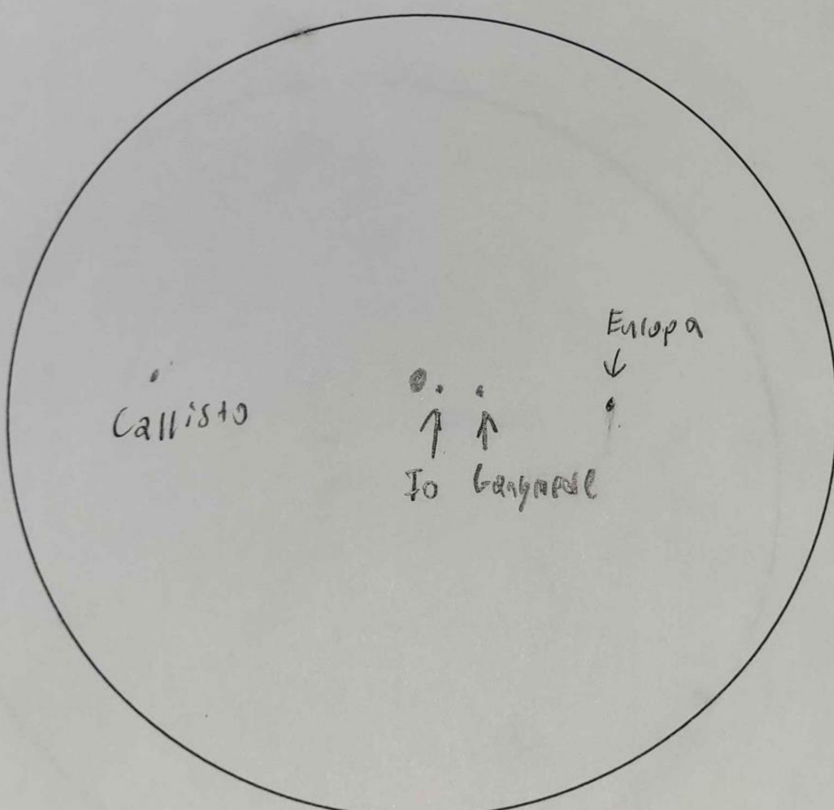
Object: Jupiter

Altitude and Direction: 14 deg, 73 deg

Date: Nov 2nd

Time: 9:10 PM

Observers: Dennis James



Galileo Project - Observations

Object: Jupiter

Altitude and Direction: 45°, 10[illegible]°

Date: Nov 29 2024

Time: 9:40 PM

Observers: Dennis Marton James Marton

Galileo Project - Observations

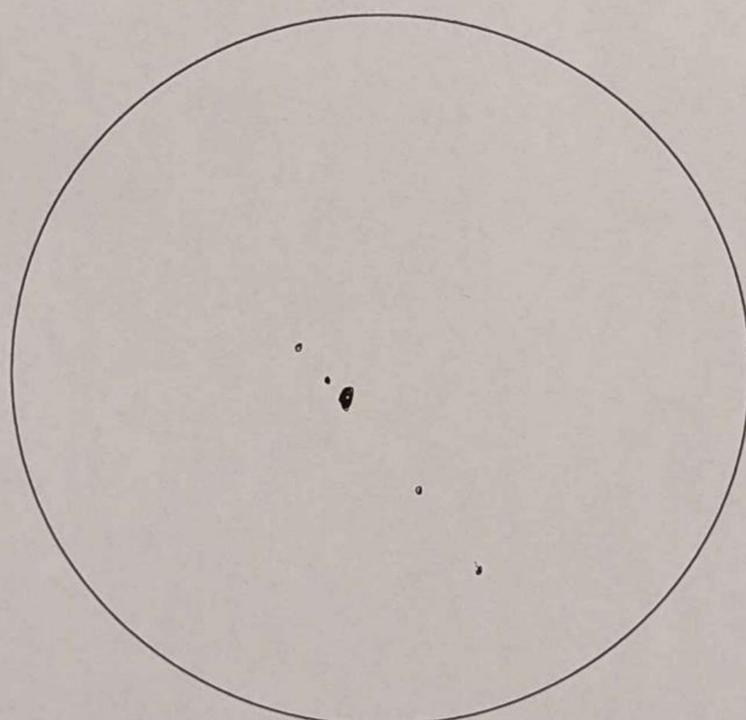
Object: Jupiter

Altitude and Direction: 67°, 160°

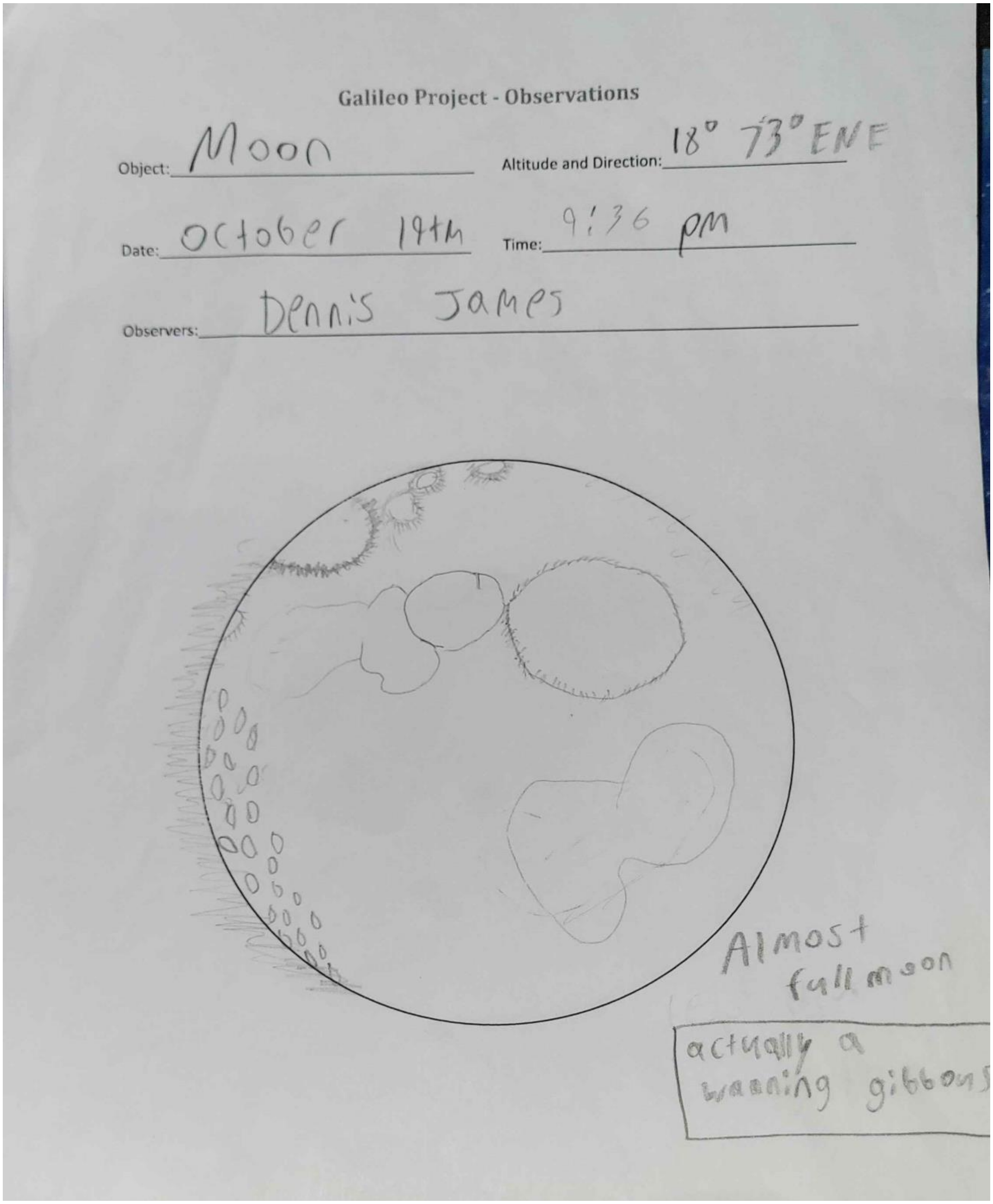
Date: Dec 1 2024

Time: 11:50

Observers: Dennis Martin James Martin



Appendix B: Moon Observations


Galileo Project - Observations

Object: Moon

Altitude and Direction: 18° 73° ENE

Date: October 19th

Time: 9:36 pm

Observers: Dennis James

Almost full moon

actually a waning gibbous

Galileo Project - Observations

Object: Moon

Altitude and Direction: 25° 195° SSW

Date: NOV 1St 2024

Time: 2:00 pm

Observers: conceptual.

use This fact during your analysis of The moon's phases

New moon

Galileo Project - Observations

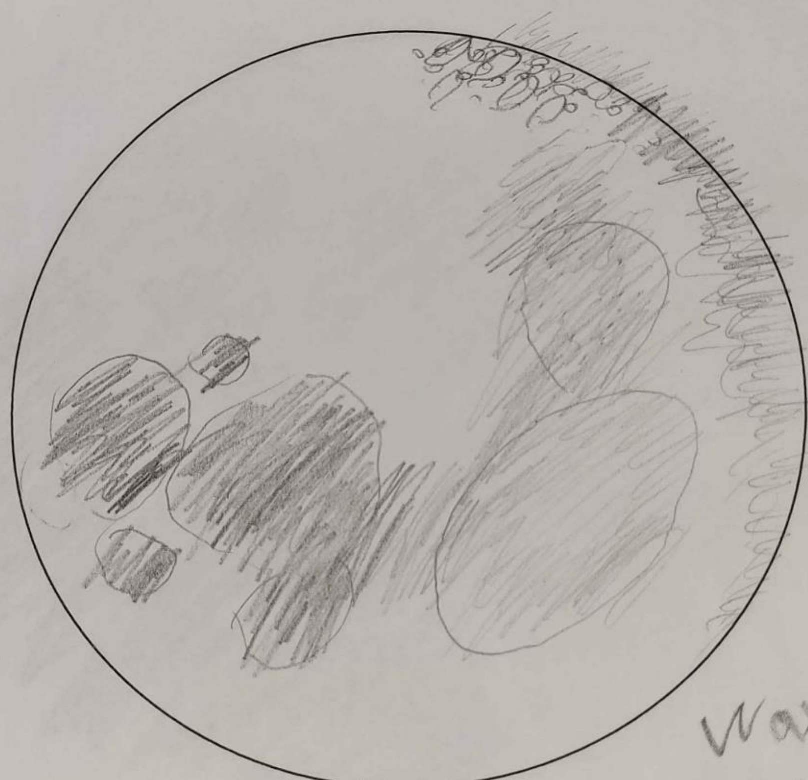
Object: The moon

Altitude and Direction: 44° 142° SE

Date: Nov 12th

Time: 7:10 pm

Observers: Dennis James



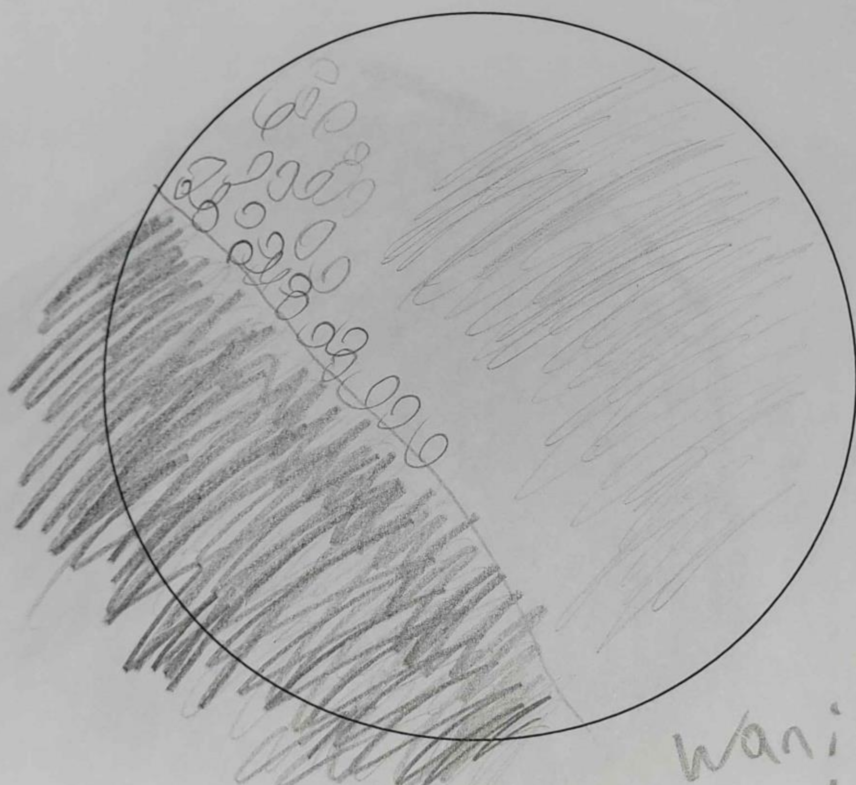
Waxing
Gibbons

Galileo Project - Observations

Object: Moon Altitude and Direction: 10,7° 83.40° E

Date: Nov 23rd Time: 12;46 am

Observers: James M Dennis



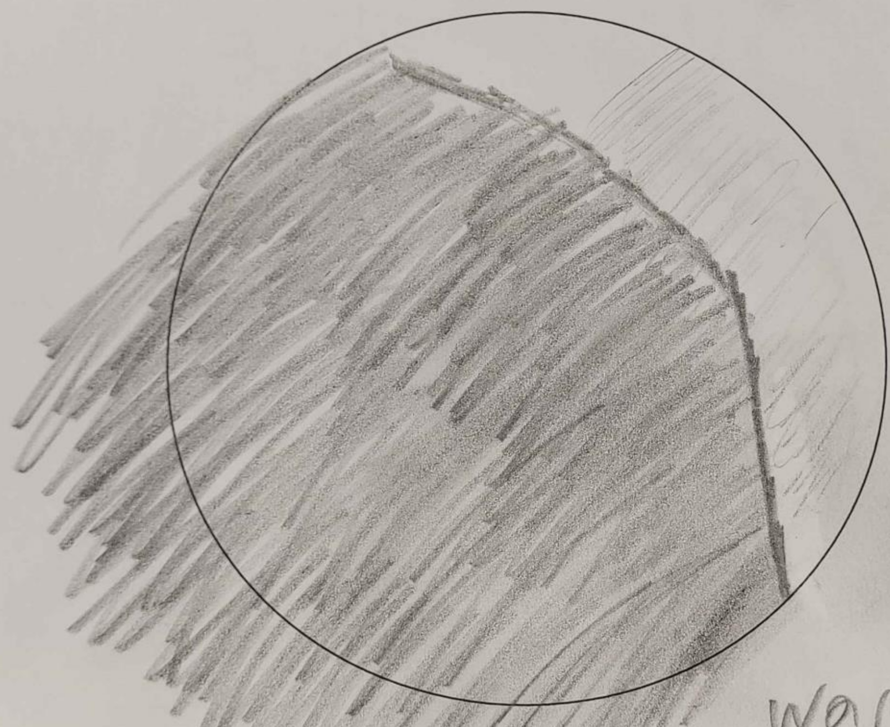
Waning Gibbous

Galileo Project - Observations

Object: The Moon   Altitude and Direction: 4° 100° ESE

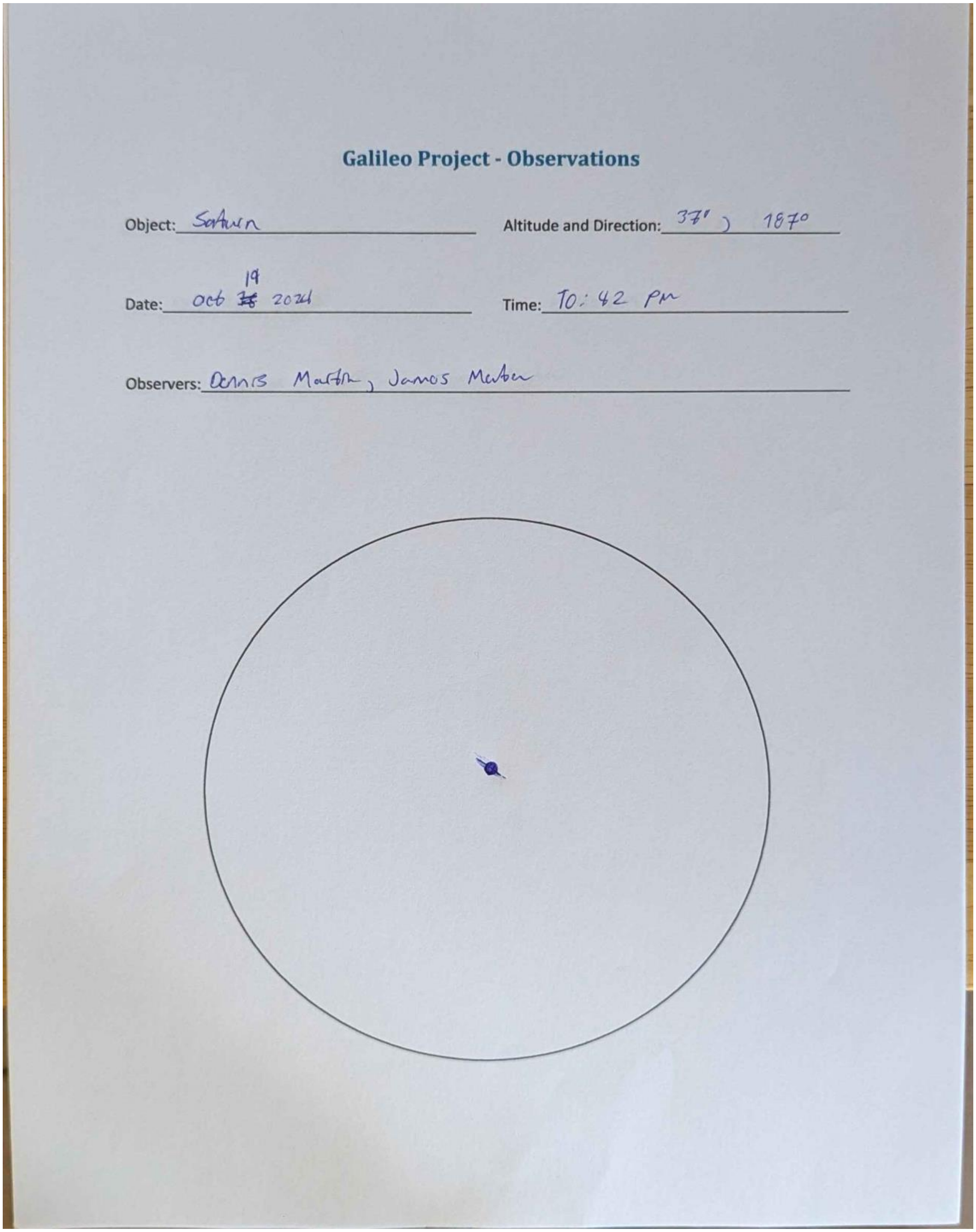
Date: Nov 26th 2024   Time: 3:17 am

Observers: James Mata



waning crescent

Appendix C: Saturn Observations



Galileo Project - Observations

Object: Saturn

Altitude and Direction: 37°, 187°

Date: oct ~~18~~ 19 2024

Time: 10:42 pm

Observers: Dennis Martin, James Martin

Galileo Project - Observations

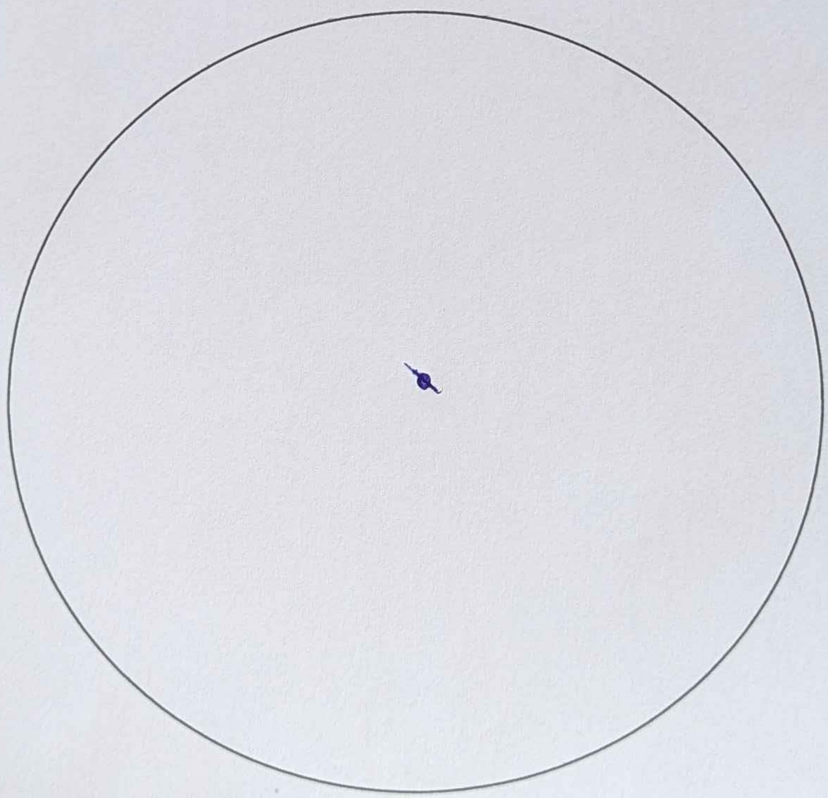
Object: Saturn

Altitude and Direction: 35°, 180°

Date: Oct 26 2024

Time: 8:40 PM

Observers: Dennis Matar, James Matar



Galileo Project - Observations

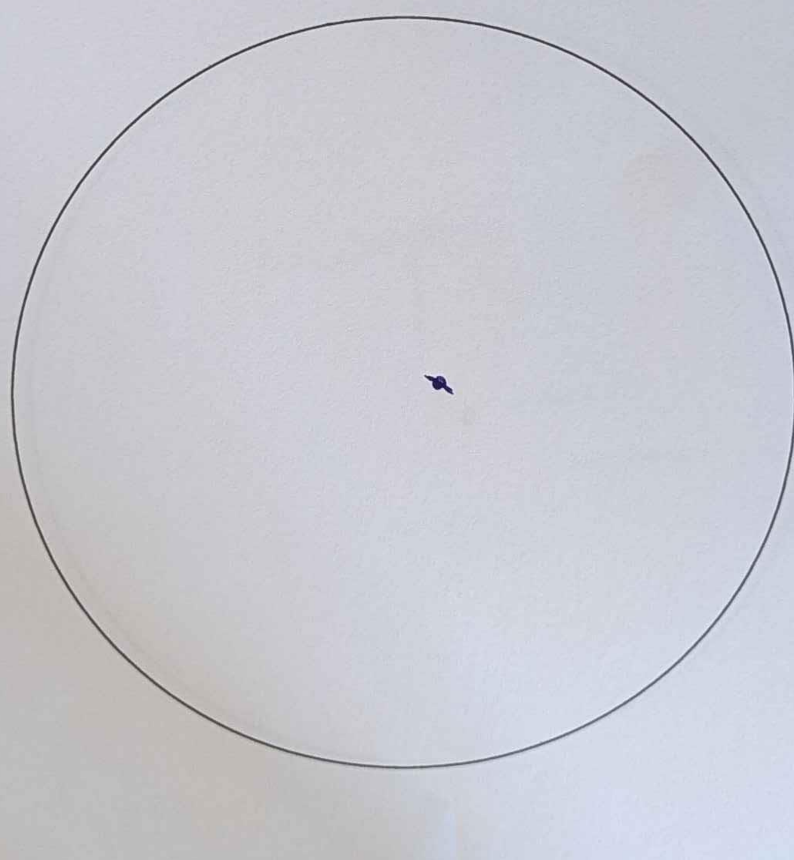
Object: Saturn

Altitude and Direction: 37°, 180°

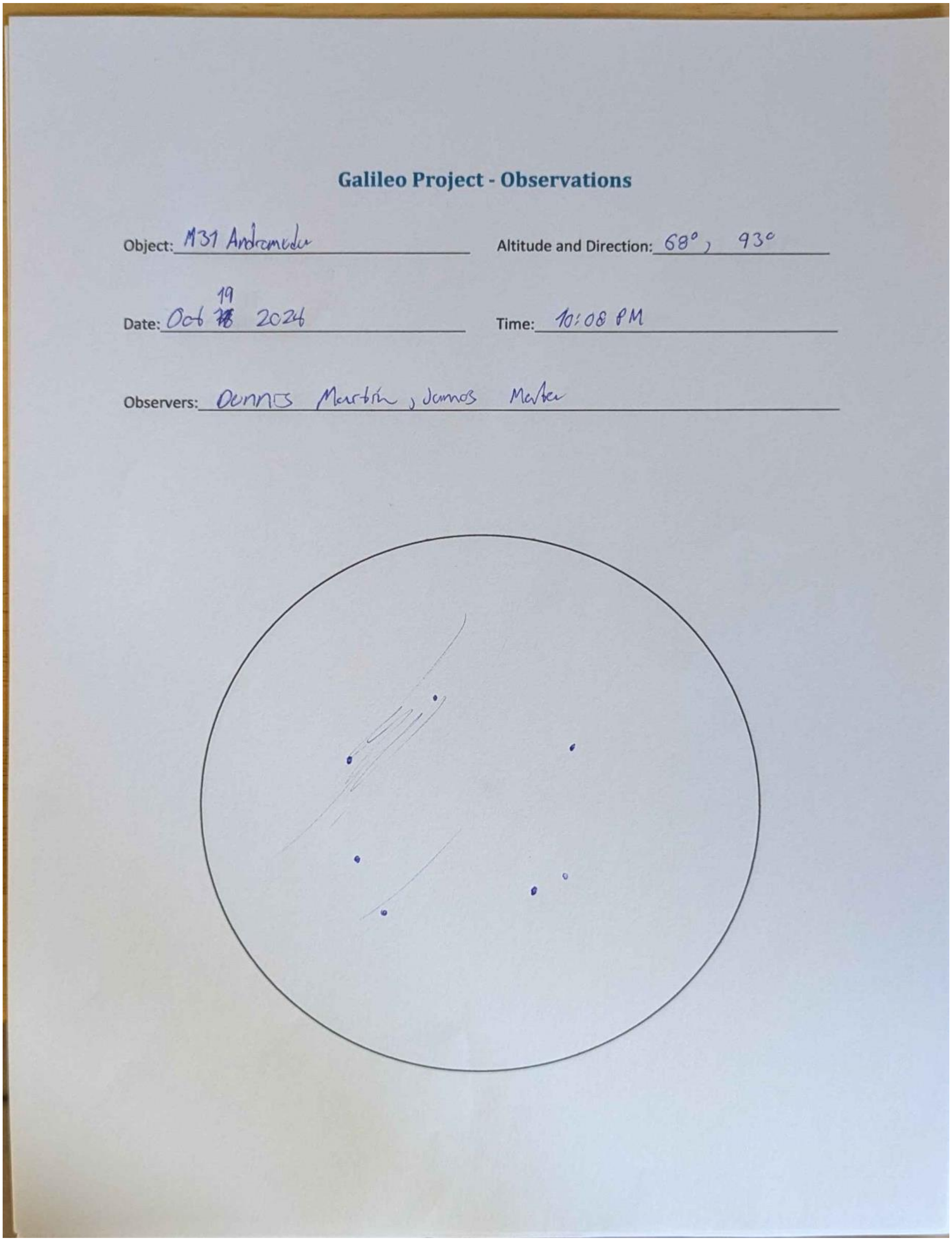
Date: Nov 2 2024

Time: 9:30 PM

Observers: Dennis Martin, James Martin



Appendix D: M31 Andromeda Observations



Galileo Project - Observations

Object: M31 Andromeda

Altitude and Direction: 68°, 93°

Date: Oct ~~18~~ 19 2024

Time: 10:08 PM

Observers: Dennis Martin, James Marter

Galileo Project - Observations

Object: M31 Andromeda

Altitude and Direction: 85°, 357°

Date: Oct 26 2024

Time: 9:00 PM

Observers: Dennis Martin, James Mata