Galileo Galilei

and the

Scientific Revolution

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Overview

Before Galileo Galilei was born in 1564, most people believed in old theories from the Greek scientists and philosophers, like Aristotle, that were based on common sense. Even though over time these theories were proved to be incorrect and flawed, people believed in them at the time. Galileo's greatest triumphs were his discoveries that many of the old theories were inaccurate. He tested and altered them and made his own theories that he proved with experimentation. Tragically, the Catholic Church did not approve of his theories and beliefs because they thought that they contradicted the Bible. He spent his last years under house arrest, but many of his discoveries and theories were proven correct are still used today.

Early Astronomy and Science in the Renaissance

The Earth-centered model of the solar system was first developed by the Greeks. Later, a man named Claudius Ptolemy developed a more refined model of the solar system building on the ideas of the Greeks.[1] His model was highly regarded and became the model for understanding and presenting the known solar system with the Earth at the center. The Ptolemaic model was not challenged for over 1,300 years.[2] In 1543, the Ptolemaic model was challenged for the first time by a man named Nicolaus Copernicus.[3] Copernicus was born in 1473 in Poland.[4] He went to school and studied math and astronomy. He is known for introducing the idea of a Sun-centered solar system. He thought the sun was in the center for two main reasons: one being that the Ptolemaic model was good, but its predictions of the positions of the planets

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[1] "The Copernican Model (A.k.a Sun Centered)." *Latitude*, www.polaris.iastate.edu/EveningStar/Unit2/unit2_sub2.htm.
[2] "The Copernican Model (A.k.a Sun Centered)." *Latitude*, www.polaris.iastate.edu/EveningStar/Unit2/unit2_sub2.htm.
[3] "The Copernican Model (A.k.a Sun Centered)." *Latitude*, www.polaris.iastate.edu/EveningStar/Unit2/unit2_sub2.htm.
[4] "Glencoe/McGraw-Hill." *Glencoe/McGraw-Hill*, jat.glencoe.com/.

were getting worse as the years passed.[5] The second reason was that he didn't like the explanation of the retrograde movement of the planets.[6] He thought that it could be explained better and easier by the Earth moving around the Sun instead of the Sun moving around the Earth. Copernicus's Sun-centered, or heliocentric model, became known as the Copernican model (Appendix A).

After the fall of the Roman Empire, the belief in Greek scientific theories declined over the years due to people wanting to learn more about the study and works of God. However, in the Middle Ages, Europeans decided to believe in the Greek and Roman theories again. At that time they never thought that it was possible that the Greeks and Romans could be wrong. However, the Greek and Roman works and theories were poorly preserved, and as copies were made, more errors were added. Although the Greeks' works had been badly preserved in some places, the Arabs and Jews in the Islamic Empire preserved the Greek and Roman works well. They carefully copied them into the Arabic language and distributed them to their people. During the same time, the Islamic Empire made advancements in science, astronomy and medicine. Then during the 1100s, Europeans became interested in science again and made contact with the Islamic Empire.[7] Larger scientific works of the Islamic Empire were brought to Europe and translated into Latin. Hindu-Arabic numbers were brought over and replaced the Roman numerals. At the same time, Europeans built universities, explored, and expanded their scientific knowledge. By the 1500s, they started to abandon old ideas and theories.[8] They started realizing

[5] "The Copernican Model (A.k.a Sun Centered)." *Latitude*, www.polaris.iastate.edu/EveningStar/Unit2/unit2_sub2.htm.
[6] "The Copernican Model (A.k.a Sun Centered)." *Latitude*, www.polaris.iastate.edu/EveningStar/Unit2/unit2_sub2.htm.
[7] "Glencoe/McGraw-Hill." *Glencoe/McGraw-Hill*, jat.glencoe.com/.
[8] "Glencoe/McGraw-Hill." *Glencoe/McGraw-Hill*, jat.glencoe.com/.

that to learn you had to experiment and test with mathematics too. This new way of thinking revolutionized science. Each new discovery changed the way they thought and they began to question traditional ways of thinking. This was the start of the Scientific Revolution.

Galileo's Triumphs

Galileo was an Italian scientist that made many great breakthroughs during the Scientific Revolution. He believed that you learn new things by experimenting and testing. Galileo was also one of the few who, at the time, supported Copernicus's ideas and theories about the Sun-centered universe. Galileo also improved the telescope by making it more powerful. Early telescopes were mainly used to make Earthbound observations. After hearing about the "Danish Perspective Glass" in 1609, Galileo constructed his own telescope and turned it towards the sky.[9] His initial telescope made objects appear three times larger than they did with the naked eye.[10] He demonstrated his telescope in Venice and this earned him a lifelong lectureship. After his success, Galileo focused on refining the instrument. Through more work, he developed an instrument that could eventually magnify an object up to thirty times their original size.[11]

Another triumph in astronomy that Galileo experienced was finding out that the shape of the moon is not a perfect sphere. Using a combination of the telescope that he refined, his

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[9] "Galileo and the Telescope | Modeling the Cosmos | Articles and Essays | Finding Our Place in the Cosmos: From Galileo to Sagan and Beyond | Digital Collections | Library of Congress." *Planning D-Day (April 2003) - Library of Congress Information Bulletin*, Victor, www.loc.gov/collections/finding-our-place-in-the-cosmos-with-carl-sagan/articles-and-essays/modeling-the-cosmos/galileo-and-the-telescope.

[10] "Galileo and the Telescope | Modeling the Cosmos | Articles and Essays | Finding Our Place in the Cosmos: From Galileo to Sagan and Beyond | Digital Collections | Library of Congress." *Planning D-Day (April 2003) - Library of Congress Information Bulletin*, Victor, www.loc.gov/collections/finding-our-place-in-the-cosmos-with-carl-sagan/articles-and-essays/modeling-the-cosmos/galileo-and-the-telescope.

[11] "Galileo and the Telescope | Modeling the Cosmos | Articles and Essays | Finding Our Place in the Cosmos: From Galileo to Sagan and Beyond | Digital Collections | Library of Congress." *Planning D-Day (April 2003) - Library of Congress Information Bulletin*, Victor, www.loc.gov/collections/finding-our-place-in-the-cosmos-with-carl-sagan/articles-and-essays/modeling-the-cosmos/galileo-and-the-telescope.

training in Renaissance art and a shading technique called Chiaroscuro, Galileo was able to determine that the moon's shape is not a perfect sphere. Galileo used his telescope to take closer looks at the moon and drew sketches of it using Chiaroscuro. Analyzing his drawings led Galileo to conclude that Aristotle's theory of the moon being a perfect sphere was incorrect. Even though Thomas Harriot observed the moon around the same time and came to nearly the same conclusion, Galileo was the first to publish and distribute his information to the public in *Starry Messenger* in 1610.[12]

Using the telescope, Galileo also observed that Jupiter had its own moons. At first, he thought that Jupiter was just three unobserved stars. As he continued to study them, he discovered that they weren't located in the same spot every night. After a few days, Galileo came to the conclusion that these new stars were actually orbiting Jupiter. When Galileo discovered this, he used this new information as further evidence of a heliocentric universe. Many people agreed that Jupiter was in motion, so Jupiter having its own moons offered a great critique to the theory of the Ptolemaic model. Galileo published this theory in 1610, and later Simon Marius built on it and made it more accurate in 1614.[13]

A man named Johannes Kepler was alive at the same time as Galileo, and Kepler's school teacher was one of the few that supported the theory of a heliocentric universe. Kepler later became a supporter of the heliocentric theory as well for "physical or, if you prefer,

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[12] "Galileo and the Telescope | Modeling the Cosmos | Articles and Essays | Finding Our Place in the Cosmos: From Galileo to Sagan and Beyond | Digital Collections | Library of Congress." *Planning D-Day (April 2003) - Library of Congress Information Bulletin*, Victor,www.loc.gov/collections/finding-our-place-in-the-cosmos-with-carl-sagan/articles-and-essays/modeling-the-cosmos/galileo-and-the-telescope.

[13] "Galileo and the Telescope | Modeling the Cosmos | Articles and Essays | Finding Our Place in the Cosmos: From Galileo to Sagan and Beyond | Digital Collections | Library of Congress." *Planning D-Day (April 2003) - Library of Congress Information Bulletin*, Victor,www.loc.gov/collections/finding-our-place-in-the-cosmos-with-carl-sagan/articles-and-essays/modeling-the-cosmos/galileo-and-the-telescope.

metaphysical reasons."[14] In 1594, Kepler became a mathematics professor.[15] In 1597, he published his first important work called *The Cosmographic Mystery* [16] where he argued for the Copernican model. His book was very accurate except for the planet Mercury.[17] In 1610, Kepler heard about Galileo's discoveries and he wrote a long letter of support to Galileo, gained access to a telescope and published his own works and observations about Jupiter.[18] Both Kepler's letter and observations greatly helped Galileo as his works were not widely accepted at the time. Kepler and Galileo were longtime correspondents and wrote many letters to each other discussing different theories and experiences. In 1610, Galileo wrote a letter to Kepler expressing his frustration and disappointment when he was unsuccessful in trying to gain more support for his theories.[19] In the letter he wrote, "My dear Kepler, what would you say of the learned here, who, replete with the pertinacity of the asp, have steadfastly refused to cast a glance through the telescope? What shall we make of this? Shall we laugh, or shall we cry?"[20] In his letter to Kepler, Galileo was expressing his disappointment with the public and the Catholic Church's beliefs in the older theories and having no interest in considering new ideas.

Galileo was a great experimenter and inventor. He also challenged Aristotle's theories about how the weight of an object affects how fast it will fall. He proved Aristotle wrong through experimentation. At age 19, Galileo discovered the isochronism, or length of the period, of the pendulum.[21] When he was 22, he invented the hydrostatic balance, which is a scale used to

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[14] *The Galileo Project | Biography | Pendulum*, galileo.rice.edu/sci/kepler.html.
[15] *The Galileo Project | Biography | Pendulum*, galileo.rice.edu/sci/kepler.html.
[16] *The Galileo Project | Biography | Pendulum*, galileo.rice.edu/sci/kepler.html.
[17] *The Galileo Project | Biography | Pendulum*, galileo.rice.edu/sci/kepler.html.
[18] *The Galileo Project | Biography | Pendulum*, galileo.rice.edu/sci/kepler.html.
[19] User, Super. "The Trial of Galileo: An Account." *Famous Trials*, www.famous-trials.com/galileotrial/1014-home.
[20] User, Super. "The Trial of Galileo: An Account." *Famous Trials*, www.famous-trials.com/galileotrial/1014-home.
[21] User, Super. "The Trial of Galileo: An Account." *Famous Trials*, www.famous-trials.com/galileotrial/1014-home.

determine an object's density.[22] At the age of 25 he was awarded the Chair of Mathematics at the University of Pisa in Italy.[23] Galileo also proposed an early theory of relativity and studied inertia which later Newton based his First Law of Motion on.[24] Galileo gained a reputation as a great thinker, scientist, mathematician, a good teacher and lecturer.[25] Later, in 1632, Galileo published his works and findings in *Dialogue Concerning Two Chief World Systems* (Appendix B).[26] Using Galileo's findings, thoughts, and discoveries, the Scientific Revolution continued with more individuals who expanded and bettered the world of scientific research and knowledge.

Galileo's Tragedies

When Galileo first built his telescope, he began to piece together evidence and openly support the Copernican model. Even though Copernicus was correct in his astronomical thinking, his thinking challenged the thoughts of Aristotle, and therefore, the beliefs of the Catholic Church. In 1613, Galileo wrote a letter explaining how the theory of the heliocentric universe did not contradict the Bible.[27] In his letter, he stated that "... scripture was written from an earthly perspective and implied that science provided a different, more accurate perspective."[28] Galileo's letter became public and the Church declared the Copernican theory heretical. The Catholic Church, in 1616, placed Copernicus's book about the heliocentric universe on the 'Banned Books' list because it did not agree with the Bible that the Earth was the center of the universe.[29]

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[22] User, Super. "The Trial of Galileo: An Account." *Famous Trials*, www.famous-trials.com/galileotrial/1014-home.
[23] "Home." *Famous Scientists*, www.famousscientists.org/galileo-galilei/.
[24] "Home." *Famous Scientists*, www.famousscientists.org/galileo-galilei/.
[25] User, Super. "The Trial of Galileo: An Account." *Famous Trials*, www.famous-trials.com/galileotrial/1014-home.
[26] "Galileo's Vain Ambition." *Buy the Truth*, 27 May 2011, buythetruth.wordpress.com/2011/05/25/galileos-vain-ambition/.
[27] "Galileo." *Biography.com*, A&E Networks Television, 9 Jan. 2019, www.biography.com/people/galileo-9305220.
[28] "Galileo." *Biography.com*, A&E Networks Television, 9 Jan. 2019, www.biography.com/people/galileo-9305220.
[29] Editors, History.com. "Galileo Galilei." *History.com*, A&E Television Networks, 23 July 2010, www.history.com/topics/inventions/galileo-galilei#section_3.

Galileo was then ordered by the Church not to "...hold, teach, or defend..." the Copernican theory in any way.[30] Galileo obeyed this for seven years for two main reasons: one to make life easier for himself, and the second, because he was Catholic himself.[31]

In 1623, Galileo's friend, Cardinal Maffeo Barberini was elected Pope and took the name Pope Urban VIII.[32] He allowed Galileo to pursue his work and even encouraged Galileo to publish his works as long as he didn't mention Copernicus's theory or the heliocentric universe. However, Galileo published his book *Dialogue Concerning the Two Chief World Systems* in 1632.[33] Against the law, this book advocated and addressed the Copernican theory. Galileo was told again by the Catholic Church that he was not allowed to support Copernicus's theories anymore since they disagreed with the Bible. Even though he was warned not to, Galileo continued to research and improve his theories. Galileo was summoned to the Roman Inquisition, which was the powerful offices of the Catholic Church in 1633, where he was put on trial and questioned.[34] During his trial, Galileo was treated with respect and was never imprisoned. However, in a final attempt to break him, the Catholic Church threatened Galileo with torture and he was "...forced to express sorrow and curse his errors."[35]

Galileo was convicted of heresy and was sentenced to house arrest.[36] Galileo was 70 at

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[30] "Galileo." *Biography.com*, A&E Networks Television, 9 Jan. 2019, www.biography.com/people/galileo-9305220.
[31] "Galileo." *Biography.com*, A&E Networks Television, 9 Jan. 2019, www.biography.com/people/galileo-9305220.
[32] "Galileo." *Biography.com*, A&E Networks Television, 9 Jan. 2019, www.biography.com/people/galileo-9305220.
[33] User, Super. "The Trial of Galileo: An Account." *Famous Trials*, www.famous-trials.com/galileotrial/1014-home.
[34] Editors, History.com. "Galileo Galilei." *History.com*, A&E Television Networks, 23 July 2010, www.history.com/topics/inventions/galileo-galilei#section_3.
[35] Editors, History.com. "Galileo Galilei." *History.com*, A&E Television Networks, 23 July 2010, www.history.com/topics/inventions/galileo-galilei#section_3.
[36] "Galileo." *Biography.com*, A&E Networks Television, 9 Jan. 2019, www.biography.com/people/galileo-9305220.

the time of his trials, and spent the last nine years of his life under house arrest where he wrote a summary of his works and experiments.[37] While he was under house arrest, he was not to have visitors or have his work published outside of Italy. However, in 1634, a French translation of his works was published, and a year later, copies of *The Dialogue* were made and published in Holland.[38] Galileo wrote another book called *Two New Sciences* that was published in Holland in 1638.[39] Over the years, Galileo's health declined and he eventually became blind. Galileo died on January 8, 1642 in Arcetri, which is near Florence, Italy, with a high fever and heart palpitations.[40]

As the years passed, the Catholic Church could no longer deny the scientific proof about heliocentrism. They lifted the ban on most books about heliocentrism in 1758.[41] In 1835, the church dropped its disagreements with heliocentrism altogether.[42] In the 20th century, both Pope Pius XII and Pope John Paul II voiced their regret for how the Church had treated Galileo.[43]

Galileo's Legacy

Many of Galileo's experiments and theories shed light on the path for many others. For instance, Galileo's motion experiments helped Isaac Newton develop the Codification of Classical Mechanics.[44] After Galileo's death, his proof of the heliocentric universe later became

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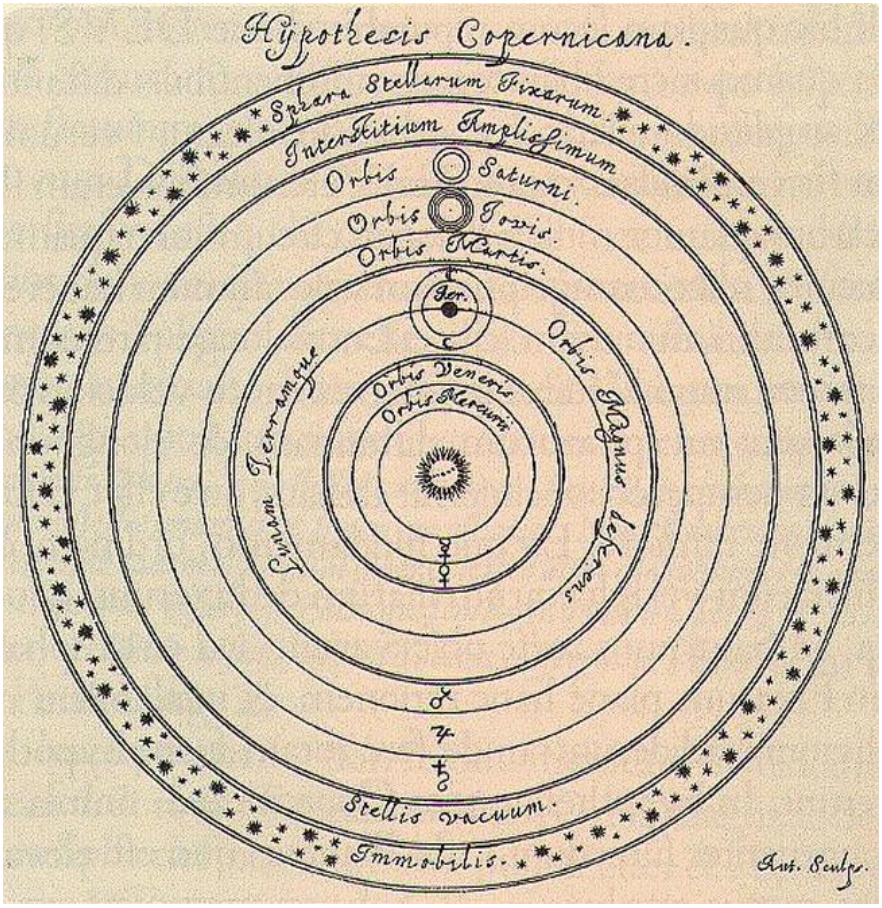
[37] Editors, History.com. "Galileo Galilei." *History.com*, A&E Television Networks, 23 July 2010, www.history.com/topics/inventions/galileo-galilei#section_3.
[38] "Galileo." *Biography.com*, A&E Networks Television, 9 Jan. 2019, www.biography.com/people/galileo-9305220
[39] "Galileo." *Biography.com*, A&E Networks Television, 9 Jan. 2019, www.biography.com/people/galileo-9305220
[40] Galileo." *Biography.com*, A&E Networks Television, 9 Jan. 2019, www.biography.com/people/galileo-9305220
[41] Galileo." *Biography.com*, A&E Networks Television, 9 Jan. 2019, www.biography.com/people/galileo-9305220
[42] "Galileo." *Biography.com*, A&E Networks Television, 9 Jan. 2019, www.biography.com/people/galileo-9305220
[43] "Editors, History.com. "Galileo Galilei." *History.com*, A&E Television Networks, 23 July 2010, www.history.com/topics/inventions/galileo-galilei#section_3.
[44] VanDervoort, Oliver. "Galileo's Effects on Science Today." *Sciencing.com*, Sciencing, 10 Jan. 2019, sciencing.com/galileos-effects-science-today-8214085.html.

fact and was accepted. His other inventions and improvements to scientific instruments played a large part in revolutionizing biology, astronomy, physics and other areas of science. He later became known as "...the father of experimental physics."[45] His love of experimentation and testing helped shape the scientific method we know and use today.

Galileo Galilei was a very important man to both the science and astronomy we know and use today. Tragically, the Catholic Church disagreed with him during his life, but we still remember him today for his many triumphs.

[45] User, Super. "The Trial of Galileo: An Account." *Famous Trials*, www.famous-trials.com/galileotrial/1014-home.

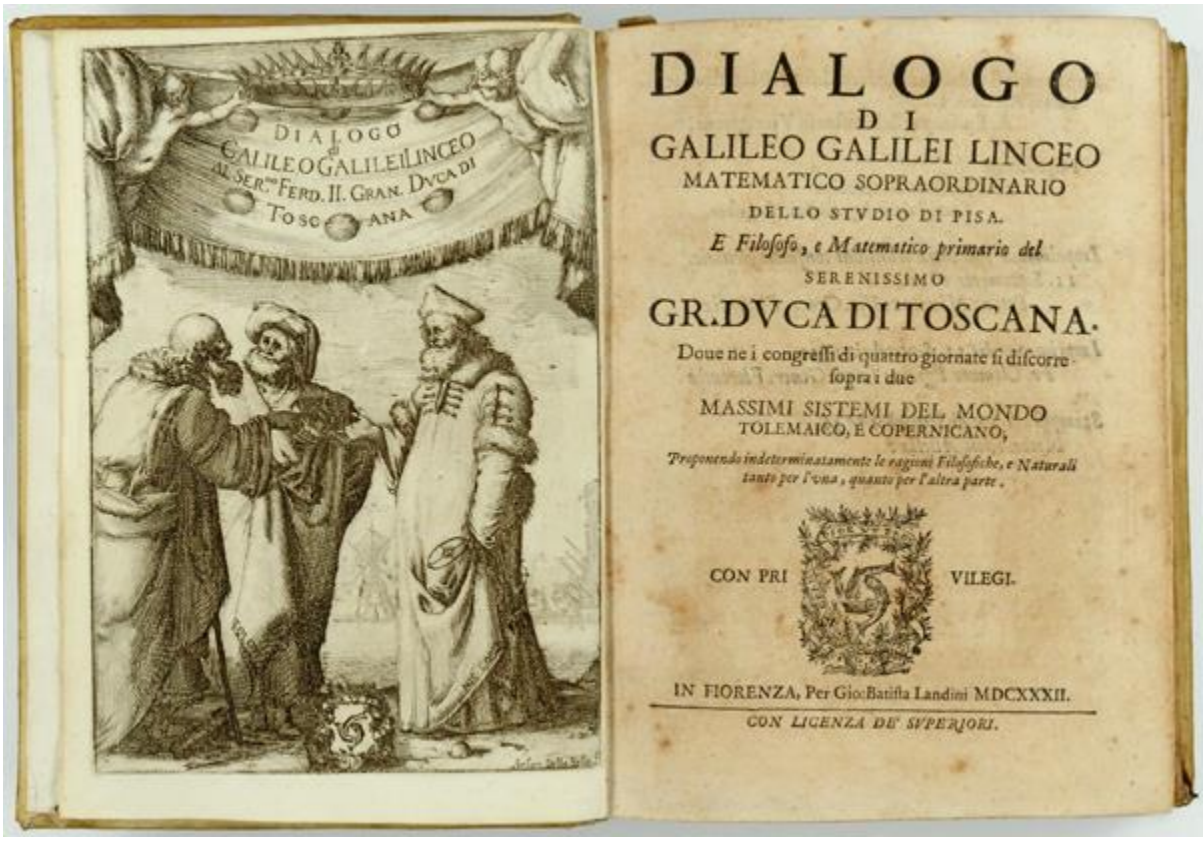
Appendix A



"The Copernican Revolution." *Red and Brown Dwarfs*, astro.hopkinsschools.org/course_documents/history/copernicus_to_galileo/copernicus.htm.

This is one of Corpercornius's early drawings of the theory of the heliocentric universe. This model shows the plants all orbiting around the Sun instead of orbiting around the Earth as they did in the Ptolemaic model. This was important because the Ptolemaic model was the model that everyone believed in during the time of Galileo.

Appendix B



"Galileo's Vain Ambition." *Buy the Truth*, 27 May 2011, buythetruth.wordpress.com/2011/05/25/galileos-vain-ambition/.

This is what the early cover of Galileo's book *Dialogue Concerning Two Chief World Systems* looked like. Galileo wrote this book addressing the debate about the heliocentric universe. After this, Galileo was summoned to a trial by the Catholic Church and then placed under house arrest for his last years.

Annotated Bibliography

Primary Sources

Galilei, Galileo, and Johannes Kepler. "Correspondence between Galileo Galilei and Johannes Kepler." *Letters between Galileo and Kepler and Pope Condemnation of Galileo*, Galileo Galilei and Johannes Kepler, www.nv.k12.wa.us/site/handlers/filedownload.ashx?moduleinstanceid=743&dataid=1240&FileName=Letters_between_Galileo_and__Kepler_and_Pope_Condemnation_of_Galileo.pdf.

This letter was one of the letters that Galileo wrote to Kepler. From this letter I learned many valuable pieces of information about what Galileo and Kepler talked about. I used this letter in my triumphs section because Kepler greatly helped Galileo. This source was very helpful.

"Galileo Galilei Quotes." *BrainyQuote*, Xplore, www.brainyquote.com/authors/galileo_galilei.

This website had many quotes from Galileo. From these quotes I learned what Galileo really said and what he thought. I used this in my triumphs and in my tragedy sections. I learned many valuable things from his quotes.

"Galileo's Vain Ambition." *Buy the Truth*, 27 May 2011, buythetruth.wordpress.com/2011/05/25/galileos-vain-ambition/.

This picture was very helpful because I was able to see what his book really looked like. From this picture I learned what his published works looked like. I used this as Appendix B. This was a useful source.

Galilie, Galileo. “Letter to the Grand Duchess Christina of Tuscany.” *Galileo-LetterDuchessChristina*, Galileo Galilie, web.stanford.edu/~jsabol/certainty/readings/Galileo-LetterDuchessChristina.pdf.

This letter showed what Galileo thought about when he was writing to the Duchess. I was able to see what he thought firsthand based on this letter. I used this in my tragedy paragraphs because he was complaining of his situation and the public input.

“The Copernican Revolution.” *Red and Brown Dwarfs*, astro.hopkinsschools.org/course_documents/history/copernicus_to_galileo/copernicus.htm.

This drawing of the Copernican model included a picture of the Copernican theory. From this I could visualize what it really looked like. I used this as Appendix A so that everyone could see what it looks like too. This was a very good visual.

Secondary Sources

Editors, History.com. "Galileo Galilei." *History.com*, A&E Television Networks, 23 July 2010, www.history.com/topics/inventions/galileo-galilei#section_3.

This is website where I gained lots of valuable information. In this source I gained lots of information about Galileo's life such as his trial and his legacy. I used information from this source throughout my essay in both the triumph, tragedy and legacy paragraphs. This was a very valuable source of information.

"Enlightenment and Revolution." *Chapter 18: Enlightenment and Revolution 22 / 52*, www.boone.kyschools.us/docs/building/9/unit 5 chapter 18.pdf.

This website included information about science and astronomy during the Renaissance before Galileo was born. From this source I gained information about astronomical and scientific beliefs before Galileo's time. I used this source mostly for the background section but also touching on some of the most influential points in the triumph section. This was a very useful source.

"Galileo and the Telescope | Modeling the Cosmos | Articles and Essays | Finding Our Place in the Cosmos: From Galileo to Sagan and Beyond | Digital Collections | Library of Congress." *Planning D-Day (April 2003) - Library of Congress Information Bulletin*, Victor,www.loc.gov/collections/finding-our-place-in-the-cosmos-with-carl-sagan/articles-and-essays/modeling-the-cosmos/galileo-and-the-telescope.

This website gave me very valuable information about Galileo's successes. In this source there was very good information about Galileo's triumphs in astronomy. This source also

included some information of how Galileo made these amazing discoveries. I used this source in the triumphs section going into detail of how each new discovery was made. This source was very helpful and I gained valuable information from it.

"Galileo." *Biography.com*, A&E Networks Television, 9 Jan. 2019, www.biography.com/people/galileo-9305220.

This website showed an overview of Galileo's life and accomplishments. From this source I gained information about his many accomplishments but also learned about his tragedies. I used this source in both the triumph section and also the tragedy section. This was a very useful source.

"Glencoe/McGraw-Hill." *Glencoe/McGraw-Hill*, jat.glencoe.com/.

This is the PDF from Chapter 18 where I first got the information about the scientists before Galileo. I used this information for background in the Early Astronomy and Science in the Renaissance section of my paper. This source was very helpful.

"Home." *Famous Scientists*, www.famousscientists.org/galileo-galilei/.

This is a source where I found out more information about Galileo's accomplishments and inventions. I used this source in the triumphs section. This was very helpful.

"The Scientific Revolution." *Isaac Newton Biography - Newton's Life, Career, Work - Dr Robert A. Hatch*, users.clas.ufl.edu/ufhatch/pages/03-Sci-Rev/SCI-REV-Teaching/03sr-definition-concept.htm.

This website tells of different sciences during the Renaissance. From this source I learned a lot about how the Scientific Revolution was started and who contributed to it. I used this information in my background section. I used this source a lot in my essay because it was very useful.

"The Copernican Model (A.k.a Sun Centered)." *Latitude*, www.polaris.iastate.edu/EveningStar/Unit2/unit2_sub2.htm.

This website tells about the earliest models of the universe and how they were believed. From this source I learned about the different models and beliefs of the universe. I used this information in the background section. This was a very helpful source with lots of information.

The Galileo Project | Biography | Pendulum, galileo.rice.edu/sci/kepler.html.

This website tells a lot about Kepler and how he helped Galileo. From this source I learned how Kepler helped Galileo by encouraging him and supporting his beliefs. I used this information in the triumphs section because Kepler helped Galileo a lot. This was very helpful.

User, Super. "The Trial of Galileo: An Account." *Famous Trials*, www.famous-trials.com/galileotrial/1014-home.

This website had lots of good information about Galileo's trial and all the details on how he was treated. From this source I learned that he was respected but later threatened with torture. I used this information in the tragedy section because this was a very sad part in his life. This was a very good source packed with information.

VanDervoort, Oliver. “Galileo's Effects on Science Today.” *Sciencing.com*, Sciencing, 10 Jan. 2019, sciencing.com/galileos-effects-science-today-8214085.html.

This website had lots of information about Galileo’s lasting legacy and effects on today. I used this information in my legacy paragraphs that tie up my essay. This was a very informative source.