

Williamina Fleming: Breaking Barriers with A Universe of Glass

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Junior Division
Individual Performance
paper 500 words

In the past, women in the sciences were often overlooked, so for National History Day, I chose to focus on an under-recognized female scientist. Early in my research, I found Williamina Paton Fleming. I was surprised I had never encountered her although I had heard of her colleagues, Annie Jump Cannon and Henrietta Leavitt. I have always loved studying the stars and am fascinated by the role of women in astronomy whose important contributions are sometimes forgotten. Williamina Fleming's unique ability to interpret astronomical photographs changed astronomy in nineteenth-century America and beyond, breaking barriers for scientists and for women.

In preliminary research, I located Harvard's digital scans of Fleming's diary and excellent period photographs, as well as many academic articles about her and other women at the Harvard Observatory. I was also privileged to interview Dr. Lindsay Smith, current Curator of Astronomical Photographs at Harvard. She was extremely helpful in suggesting sources and later reviewed the performance script. Not much is known about Fleming's early years in Scotland. After her husband abandoned her, she worked for Harvard Observatory Director Edward Pickering, who hired her for the new project to map the night sky. The process involved taking images through telescopes, then mapping all the stars in that small section of sky. Using this process, Fleming discovered stars, novae, and nebulae and encouraged the work of other astronomers, while facilitating many important discoveries.

I chose performance to give a voice to a person who has been largely unnoticed. This category also allows others to help tell her story. A professor giving a tour is used to set the scene, reciting a poem about observing the stars, while also indicating that astronomy was once seen as a job for men only. I use Fleming herself to describe the process of analyzing the astronomical photographs, and her own words from her journal explain how women were paid differently than men. Annie Jump Cannon, who lived until 1941 and wrote Fleming's obituary, discusses Fleming's legacy. The professor concludes by explaining how the plates continue to be used in the twenty-first century. The set pieces include a telescope to create the impression of being in the observatory and a table similar to the one seen in

images. Props, including the “flyspanker” I crafted, are also based on photos. I also fabricated glass plates to imitate theirs.

Some of the obstacles I encountered include the lack of reliable information about Fleming’s youth. Fleming also only kept a journal for three months; however, many of her colleagues did keep life-long journals. While creating this project, I learned much about the history and the science of astronomy and the evolution of women’s roles in science. I learned there were a variety of attitudes toward women scientists in the past. Pickering was ahead of his time hiring women, but not everyone accepted them as scientists. It is important that these women be recognized, and I hope to help reveal Fleming and her associates for the stars that they are.

Annotated Bibliography

Primary Sources

Articles

Cannon, Annie Jump. "Minor Contributions and Notes: Williamina Paton Fleming." *Astrophysical Journal*. July 1911. Vol. 34. pp. 314-317.

This obituary of Fleming was written by her friend and colleague Annie Jump Cannon. This version was for the American Astronomical Society magazine, for which Fleming often published as well. Cannon published similar obituaries with some variations in many other magazines at the time. Cannon also submitted the obituary for Fleming to *Nature* and *Scientific American*. Some of Cannon's phrases from the *Astrophysical Journal* obituary inspired the way in which Cannon's character in the performance describes Fleming's discoveries and awards.

"Death of Woman Astronomer is Loss to World of Science." *Los Angeles Times*. 25 Jun. 1911. p. III20. *ProQuest Historical Newspapers*.

This short obituary presents some of Fleming's discoveries and accomplishments in her life. It indicates that the world of science has had a horrible loss upon her death. It is interesting that this newspaper in California published the piece, but its length shows that Fleming's death was considered only a minor news item.

Fleming, Williamina. "A Field for Woman's Work in Astronomy." *Astronomy and Astrophysics* Vol 12 1893. pp.683-689.

Fleming published this article in 1895 in the *Astronomy and Astrophysics* Journal. Fleming writes of how women at the Harvard Observatory are treated well by men there, "with the greatest courtesy, encouragement, and assistance being graciously accorded." Although Fleming complained in her journal about salary inequity, she indicates here that her male co-workers were respectful of the women computers. Fleming wrote this article not long after the spectra chart was invented.

"Harvard's Women Astronomers: Work of Mrs. Fleming and Associates." *New York Times*. 12 Oct. 1904.

This short article discusses the Harvard human computers project and mentions all of the women involved in the project and some of their accomplishments.

"Obituary." *New - York Tribune*. 22 May 1911. *ProQuest*.

A small obituary about Fleming is brief and crammed into the corner of the *New - York Tribune* newspaper. Compared to the obituaries in other publications, this one is far less extensive.

Thompson, Grace Agnes. "Williamina Paton Fleming." *New England Magazine*. Sept. 1912. pp. 458-467.

This is an obituary and life summary published a year and a half after Fleming died. It covers many of her accomplishments in her career. Details include how the program was established and how Fleming

came to work at the observatory, as well as personal details, such as her enjoyment of Harvard football games. The character of the professor wears a scarf in Harvard colors not only because she is giving the tour in winter (when the Horsehead Nebula is visible), but also to show Harvard team spirit in honor of Fleming's enthusiasm for football.

“Woman Astronomer Dead.” *The New York Times*. 22 May 1911. p. 11. *ProQuest Historical Newspapers*.

Fleming's *New York Times* obituary specifically describes her as one of “the foremost astronomers of the world.” Her achievements are also listed.

“Woman Astronomer Discovered Six Out Of Nine New Stars.” *Boston Daily Globe*. 26 Aug. 1906. p. SM5. *ProQuest Historical Newspapers*.

A newspaper article written about Fleming's discoveries of six new stars, this gives details on all her discoveries up to this point. Fleming was not often mentioned by name in major newspapers before her death, so this article is important and likely reflects local interest.

“Woman Finds New Star.” *New York Times* Oct 15, 1910. p. 1. *ProQuest Historical Newspapers*.

This article states that just that evening Professor Pickering had announced that Mrs. Fleming had found a new star. It was the seventeenth new star found at Harvard in the previous 25 years.

Books

Moulton, Forest Ray. *An Introduction to Astronomy*. Macmillan, 1925.

Originally published in 1906, and reprinted numerous times until 1925, this textbook mentions “Mrs. Fleming” briefly in the section on spectra, along with “Miss Maury” and “Miss Cannon.” They are listed after “E.C. Pickering” who also appears several other times in the text. There is no other mention of the discoveries at Harvard being made by specifically Fleming or the other women at Harvard. The Harvard College Observatory is mentioned several times, along with projects on which Fleming was working, such as the variable stars, spectra, and discoveries of novae, which the text calls “temporary stars,” but the discoveries are not credited to her. The spectra charts in the performance are based on the ones in this book.

Images

“Annie Jump Cannon.” *Smithsonian Institution Archives*. https://siarchives.si.edu/collections/siris_arc_291026Ait. Accessed 12 Feb 2020.

This photograph of Harvard computer and famous astronomer Annie Jump Cannon was taken when she was older, after Fleming had passed away. This image helped shape the performance's portrayal of Cannon, who was unable to hear out of her left ear her entire life though her hearing loss worsened as she got older.

“b03512.” *Harvard Archives*. https://drive.google.com/drive/folders/0Bxujr8LbXi_JN1pVMmk2U25DTXM?hl=en, Accessed 12 Jan. 2020.

Harvard has scanned images, including this one, of many of the original glass plates the Harvard women computers marked and studied. The notes that were written on the glass were composed by Fleming and her colleagues. This particular image was used to make one of the reproduction glass plates used in the performance.

“b09307.” *Harvard Archives*. https://drive.google.com/drive/folders/0Bxujr8LbXi_JN1pVMmk2U25DTXM?hl=en. Accessed 11 Jan. 2020.

This scan of one of the many photographic plates at Harvard was used to make the reproduction plates used in the performance. There are notes written on the glass which indicate information about each star, sometimes using the systems Fleming and her co-workers created.

“b10250.” *Harvard Archives*. https://drive.google.com/drive/folders/0Bxujr8LbXi_JN1pVMmk2U25DTXM?hl=en. Accessed 13 Jan. 2020.

This photograph is one of the scans of a glass plate that was used to replicate the plates as props for the performance.

“Bruce Telescope Peru.” *Harvard University Archives* https://drive.google.com/drive/folders/0Bxujr8LbXi_JN1pVMmk2U25DTXM?hl=en Accessed 10 Jan. 2020.

The Bruce Telescope was used at Harvard’s Peru site to provide images from the Southern Hemisphere. It was named in honor of its sponsor, Catherine Wolfe Bruce, a wealthy astronomy enthusiast.

“Computers c. 1891.” *Harvard University Archives*. 1891. https://docs.google.com/document/d/1_qIE_fv7SwtbTq97qMB2ELNyZaev_kVvPwRU5SVfat8/edit
Accessed 12 Jan. 2020.

Williamina Fleming and another (unidentified) female computer are featured in this image taken in 1891. This image inspired the costume choices for Fleming in the performance as well the props and set pieces used in the performance.

“Computers c. 1898.” *Harvard University Archives*. https://drive.google.com/drive/folders/0Bxujr8LbXi_JN1pVMmk2U25DTXM?hl=en Accessed 12 Jan. 2020.

In this photograph from 1898, Fleming can be seen standing behind the other female computers, supervising their work. This image helped with an understanding of Fleming's appearance and workplace behavior and duties.

“Flyspankers.” *Harvard University Archives*. https://drive.google.com/drive/folders/0Bxujr8LbXi_JN1pVMmk2U25DTXM?hl=en. Accessed 12 Jan. 2020.

These “flyspankers” are small tools used by the Harvard female computers to compare the images on the plates. This image depicts the actual pieces used in the Observatory by Fleming and her colleagues. For the performance, a replica was crafted based on this photograph.

“Harvard Computers with Pickering 1891.” *Harvard University Archives*. https://drive.google.com/drive/folders/0Bxujr8LbXi_JN1pVMmk2U25DTXM?hl=en Accessed 12 Jan. 2020.

Fleming can be seen supervising numerous computers with Director Pickering standing in the back of the room. This image inspired the setting for the performance, as well the props, including the logbook, table, plates, magnifier, prism, and pen and ink

“Light Lectern.” *Harvard University Archives* 1901. https://drive.google.com/drive/folders/0Bxujr8LbXi_JN1pVMmk2U25DTXM?hl=en Accessed 11 Jan. 2020.

Fleming can be seen here standing in the background, supervising the work in the computers’ room. This is a close-up of the image that shows Professor Pickering in the corner, allowing for a better view of Fleming.

Journals, Diaries, Logbooks

Fleming, Williamina Paton Stevens. “Journal of Williamina Patton Fleming.” 1900. *Harvard Magazine* [https://iif.lib.harvard.edu/manifests/view/drs:3007384\\$1i](https://iif.lib.harvard.edu/manifests/view/drs:3007384$1i) Accessed 20 Nov. 2019.

This is a scan of Williamina Fleming’s journal which she kept in 1900. Several of her phrases in the presentation are from her diary. She also provided excellent descriptions of her daily work and concerns about pay. Project PHaEDRA (Preserving Harvard’s Early Data and Research in Astronomy) has been created to preserve the work of early Harvard astronomers like Fleming. Her diary is one of the pieces in the collection.

“Harvard-Smithsonian Women Computers Project -Annie Jump Cannon #35” *Smithsonian*. <https://transcription.si.edu/project/10435>. Accessed 12 Jan. 2020.

The Smithsonian is in the process of transcribing many important handwritten documents with the help of volunteers who sign up for specific pages. The journals and logbooks of the Harvard computers have been partially transcribed. Part of Cannon’s materials were consulted for the project to confirm the statement by author Dava Sobel that Cannon had poor handwriting and to get a sense of her voice.

“Harvard-Smithsonian Women Computers Project - Henrietta Swan Leavitt #24” *Smithsonian* <https://transcription.si.edu/project/9676>. Accessed 12 Jan. 2020.

Another of the items being transcribed by Smithsonian volunteers is the work of Henrietta Swan Leavitt, who is mentioned in the project for her discoveries, including creation of a formula, still used today, that allows scientists to determine the distances of stars.

“Project PHaEDRA - Annie Jump Cannon 32” *Smithsonian* <https://transcription.si.edu/project/10426> Accessed 14 Jan. 2020.

The Smithsonian is in the process of transcribing many important handwritten documents with the help of volunteers who sign up for specific pages. The journals and logbooks of the Harvard computers have been partially transcribed. This is another part of Cannon’s materials that were consulted for the project to confirm Cannon’s poor handwriting and to see her work firsthand.

Secondary Sources

Articles

Geiling, Natasha. "The Women Who Mapped the Universe and Still Couldn't Get Any Respect." *Smithsonian*. 18 Sep. 2013 <https://www.smithsonianmag.com/history/the-women-who-mapped-the-universe-and-still-couldnt-get-any-respect-9287444/> Accessed 5 Jan. 2019.

Both science and women's history are covered in this very detailed article about all the female computers at Harvard, their discoveries, and accomplishments.

Guerra, Cristela. "Women Computers' Often Couldn't Use Harvard's Telescope. They Changed Astronomy Anyway." *Boston Globe*. 17 Aug. 2017, https://drive.google.com/drive/folders/0Bxujr8LbXi_JN1pVMmk2U25DTXM. Accessed 21 Jan. 2020.

This article from the *Boston Globe* discusses the whole Harvard project of the study of the night sky. Ms. Leavitt, Ms. Cannon, Ms. Fleming, and many others are included.

Haley, Paul A. "Williamina Fleming and the Harvard College Observatory." *The Antiquarian Astronomer*. Issue 11, June 2017.

A very detailed article describes Fleming's young life and the many health issues that she had. It includes her journey with her husband to the New World. Fleming's sister and niece both worked with her briefly at Harvard. All of the stars she discovered, and their positions are also mentioned.

Hirshfeld, Alan. "Williamina Fleming: Brief Life of a Spectrographic Pioneer: 1857-1911." *Harvard Magazine*. Jan.-Feb. 2017. <https://harvardmagazine.com/2017/01/williamina-fleming>. Accessed 5 Jan. 2020.

Harvard Magazine's feature discusses how Fleming rose from a poor Scottish immigrant to a world-famous astronomer.

James, Renee. "Edward and Mina." *Astronomy*. Vol. 30, Is. 7 Jul 2002. pp 46-50. *Proquest*. Accessed 12 Jan. 2020.

This short paper's title implies Professor Pickering and Fleming were in a romance. However, there is no evidence that ever happened, and the actual article focuses only on their professional relationship.

Mack, Pamela E. "Strategies and Compromises: Women in Astronomy at Harvard College Observatory, 1870-1920." *Science History Publications* 1990.

This article, written in 1990, mentions Fleming, Cannon, Leavitt, and many others of the computers.

Powell, Alvin. "Guardians of the Sky." *The Harvard Gazette*. 19 Apr. 2016. <https://news.harvard.edu/gazette/story/2016/04/guardians-of-the-sky/>. Accessed 21 Jan. 2020.

A *Harvard Gazette* article discusses the 2016 flood of the glass plate storage room. It details how volunteers were trying to get the plates out of the water to save the ink and protect them from mold.

The plates were then sent to a recovery center and are still there today. No plates were broken, but the water did remove some of the markings on the plates.

“Williamina Fleming: The Harvard Observatory Astronomer Developed a Stellar Classification System Based on her Analyses of Thousands of Stars.” *Physics Today*, <https://physicstoday.scitation.org/doi/10.1063/pt.6.6.20190515a/full/> Accessed 12 Jan. 2020.

Discussion of all of Fleming’s accomplishments is included in this piece from *Physics Today*. First published in 1948, it is the most popular physics magazine in the world. This item was published on Fleming’s birthday.

Williams, Thomas. “The Development of Astronomy in The Southern United States 1840-1914” *JHA*, xxvii (1996). *JSTOR*. Accessed 12 Jan. 2020.

This detailed article concentrates on astronomy all across the southern United States. It only briefly mentions Harvard Observatory but provides useful historical context.

Books

Johnson, George. *Miss Leavitt’s Stars*. Norton, 2005.

Henrietta Swan Leavitt was one of the women who worked with Williamina Fleming and whose work affected astronomy. This short book by science reporter George Johnson explains how Miss Leavitt’s formula was created and how it works to calculate distances in space. Also, all of Leavitt’s discoveries are listed.

Sobel, Dava. *The Glass Universe*. Viking, 2016.

Published in 2016, this book by Dava Sobel has been very popular. This text is the most comprehensive study on the Harvard women computers. Many of the sources for Sobel’s book were also consulted for the performance, and her description of the plates as a “glass universe” is used in the performance.

Interviews

Smith, Lindsay. Email to the author. 10 Jan. 2020.

Dr. Smith, who currently supervises the care and study of the glass plates, kindly responded to emailed questions and provided access to Harvard’s collection and links to many of the valuable resources used in the project. She was also gracious enough to read the performance’s script to check for factual errors. She was very encouraging about the project. Her role as the current Curator of Astronomical Photographs inspired some aspects of the character of the Professor, who serves as the narrator.

Poetry

Whitman, Walt. “When I heard the learn’d astronomer.” *Leaves of Grass*. 1860. Doubleday, 1940.

This poem is used at the beginning of the performance to set the mood of astronomy. Whitman’s poem includes both the science and enjoyment of the stars. Emphasis is placed on the word “he” in the performance because astronomy was a man’s world in the late nineteenth and early twentieth centuries.

Videos and Podcasts

“Dava Sobel: The Glass Universe.” *Chicago Humanities Festival*. 29 Nov. 2017. <https://www.youtube.com/watch?v=RIEuezOSsx0> Accessed 7 Jan. 2020.

This is a recording of Dava Sobel giving a speech about her best-selling book, *The Glass Universe*.

“Dava Sobel: ‘The Glass Universe.’” *Talks at Google*. 20 Mar. 2017 <https://www.youtube.com/watch?v=P55QGltNvDs> Accessed 5 Jan. 2020.

Dava Sobel spoke at Google headquarters about the Harvard human computers.

“Dava Sobel: 2017 National Book Festival.” *Library of Congress*. 22 Nov. 2017 <https://www.youtube.com/watch?v=uO4rxXSY7Tw> Accessed 6 Jan. 2020.

This is a recording of one of Dava Sobel’s many speeches. While she generally gives the same lecture, her audience asks different questions each time.

“How Far Are the Stars?” *Breakthrough: The Ideas That Changed the World*. PBS <https://www.pbs.org/video/how-far-are-stars-k8syka/> Accessed 21 Jan. 2020.

Fleming, and especially her colleague Henrietta Leavitt, are important to this documentary about distance in space. The film is chronologically organized, beginning with the early human computers, like Fleming.

Newman, Alex. “A Team of Women is Unearthing the Forgotten Legacy of Harvard’s Women ‘Computers.’” 27 July 2017. *pri.org*. <https://www.pri.org/stories/2017-07-27/team-women-are-unearthing-forgotten-legacy-harvard-s-women-computers> Accessed 21 Jan. 2020.

In this podcast, Alex Newman is interviewing Dr. Lindsay Smith and asking her questions about the Harvard computers and their legacy. The information was very useful for research, and it was interesting to hear Dr. Smith’s voice after communicating with her via email.

Sobel, Dava. “The Glass Universe.” *CfAI Harvard & Smithsonian Observatory Nights*. Harvard <https://www.youtube.com/watch?v=rkAmZG-8eww> Accessed 21 Jan. 2020.

This speech by Dava Sobel was actually presented at the Harvard Observatory. Sobel explains her book and the entire project of mapping the sky. She also answers questions in this recording. Dr. Smith is mentioned, as she was leading tours of the old observatory building at the same event. Ironically, the Professor character for the performance had already been planned before the viewing of this video.

Websites

“Astronomer, 1857-1911.” *UK Learning*. <https://www.nls.uk/learning-zone/science-and-technology/women-scientists/williamina-fleming> Accessed 5 Jan. 2020.

This Scottish website discusses Fleming, her life, and her discoveries.

“Chakradhar, Shraddha. “Preserving the Astronomical Past: Are Century-old, Original Images of the Cosmos Worth Saving in an Era of Digitized Astronomy?” *PBS* 10 Dec. 2014. <https://www.pbs.org/wgbh/nova/article/astronomy-plates/> Accessed 21 Jan. 2020.

An article on the PBS website discusses the Harvard Astronomy program’s history and all that the Observatory has done in science. The continuing importance of the plates is stressed.

“Computers at Work: Astronomical Labor at the HCO at the Turn of the Century.” *Galactic Gazette*. 24 Jul. 2018. <http://www.altbibl.io/gazette/computersatwork.html>. Accessed 21 Jan. 2020.

This website is a summary of all the discoveries that the Harvard computers made during and after their work at Harvard.

“Current Status: 384,150 Plates Scanned 25,911,000,000 Magnitudes using ATLAS refcat2.” *DASCH Digital Access to a Sky Century @ Harvard*. <http://dasch.rc.fas.harvard.edu/project.php>. Accessed 21 Jan. 2020.

All the telescopes that are at Harvard are listed on this website. Included is the Great Refracting Telescope used to take many of the images Fleming analyzed.

“Fleming, Williamina Paton.” *Harvard Library*. <https://library.cfa.harvard.edu/phaedra/fleming> Accessed 5 Jan. 2020.

Harvard Library has published this short article listing all of Fleming's accomplishments in her short lifetime.

Gibbons, John. “Underpaid Women ‘Computers’ Mapped the Universe in the 19th Century.” *Smithsonian Insider*. 27 Mar. 2018. <https://insider.si.edu/2018/03/underpaid-women-computers-mapped-the-universe-in-the-19th-century/> Accessed 5 Jan. 2020.

This article presents the whole project of mapping the night sky, but it also includes the low pay of the female computers, compared to the male employees. This was also an issue that aggravated Fleming.

Guarino, Ben. “Astronomers Discover an Ancient Exploding Star after a 30-year Search.” *Washington Post*. 30 Aug. 2017. <https://www.washingtonpost.com/news/speaking-of-science/wp/2017/08/30/astronomers-discover-an-ancient-exploding-star-after-a-30-year-search/> Accessed 21 Jan. 2020.

The Washington Post published this recent article that focuses on the first confirmed White Dwarf star and how it was discovered and documented by Fleming. This star, 40 Eridani B, is mentioned in the performance.

Nelson, Sue. “Williamina Fleming: Star of Scotland.” *Finding Ada*. <https://findingada.com/shop/a-passion-for-science-stories-of-discovery-and-invention/williamina-fleming-star-of-scotland/> Accessed 20 Nov. 2019.

A women-in-STEM website, called Finding Ada, is named for early mathematician Ada Lovelace. It includes a page that tells the life story of Fleming and describes her discoveries.

Newman, Alex. "Unearthing the Legacy of Harvard's Female 'Computers.'" *BBC*. 28 Aug. 2017. <https://www.bbc.com/news/world-us-canada-40879870> Accessed 21 Jan. 2020.

The BBC website has a list that includes the accomplishments made by the Harvard women computers.

"Project PHaEDRA." *Wolbach Library*. <https://library.cfa.harvard.edu/project-phaedra> 20 Nov. 2020.

PHaEDRA is a project based out of Wolbach Library, which is working to transcribe all of the Library's collection of the Harvard computers' logs, journals, and notebooks. The Wolbach combines the collections of the Harvard College Observatory and the Smithsonian Astrophysical Observatory.

Redd, Nola Taylor. "Horsehead Nebula: Well-known Object is Hard to Find." *Space.com*. 10 July 2012. <https://www.space.com/16528-horsehead-nebula.html> accessed 12 Feb. 2020

The performance begins with pointing out the Horsehead Nebula in the night sky. This short article discusses the Horsehead Nebula, its discovery by Williamina Fleming, position, and time of year when it is over North America.

"Resources: More Info on the Women Computers." *Wolbach Library*. <https://library.cfa.harvard.edu/phaedra/resources>. Accessed 5 Jan. 2020.

This bibliography of all the library's resources about the Harvard computers includes several useful items. Since some of the resources were about the partly fictional play *Silent Sky*, they were not consulted for the project.

Smith, Lindsay. "Williamina Paton Fleming." *Project Continua*. 11 Mar. 2015, Vol. 1, <http://www.projectcontinua.org/williamina-paton-fleming/> Accessed 1 Aug. 2019.

Dr. Smith, who was interviewed for the project and currently holds the position created for Fleming, contributed this post to *Project Continua*, a historical website. The post includes many of Fleming's accomplishments.

Tarantola, Andrew, "How Harvard's Human Computers Helped Invent Modern Astronomy and how the PHaEDRA Project is Bringing their Research into the 21st Century." *Engadget*. <https://www.engadget.com/2019/02/06/how-harvards-human-computers-helped-invent-modern-astronomy/> Accessed 12 Jan. 2020.

This article describes the projects on which the Harvard human computers worked and how their work is continued today.

Williamina Fleming." *National Library of Scotland*. <https://www.nls.uk/learning-zone/science-and-technology/women-scientists/williamina-fleming> Accessed 1 Aug. 2019.

A Scottish website covers Fleming's discoveries, as she was originally from Scotland and did not become an American citizen until 1907.

"Williamina Fleming, the Boston Maid Who Discovered the Stars." *New England Historical Society*. <http://www.newenglandhistoricalsociety.com/williamina-fleming-boston-maid-discovered-stars/> Accessed 21 Aug. 2019.

This website covers Fleming's and other Harvard computers' discoveries. Focused on tourism, this website also has detailed history.

“Williamina Fleming, From Scottish Maid to Harvard Astronomer.” *New England Historical Society*. <http://www.newenglandhistoricalsociety.com/williamina-fleming-boston-maid-discovered-stars/>
Accessed 5 Jan. 2020.

Focusing on the history of Fleming's work, this article presents the life story of Fleming and briefly sums up her discoveries and accomplishments.

“Williamina Fleming: Maid to Victorian Era Astronomer.” *Racing Nellie Bly*, <https://racingnelliebly.com/weirdscience/williamina-fleming-from-maid-to-victorian-era-astronomer/>
Accessed 1 Aug. 2019.

A website dedicated to women's history includes a page about Fleming. The page describes how she went from maid to astronomer. Her role was more like that of housekeeper than maid. Because she was extremely intelligent and organized, she made an impression on Mrs. Pickering.

“Williamina Paton Stevens Fleming (1857–1911).” *Harvard Archives*. <https://web.archive.org/web/20180402041723/http://ocp.hul.harvard.edu/ww/fleming.html>. Accessed 5 Jan. 2019.

A page on the Harvard website mentions the discoveries and accomplishments of Fleming and all the other women who worked at Harvard.

NHD PERFORMANCE SCRIPT COVER PAGE

Please Note: All text in this template must be in 12 point font.
 Times New Roman, Arial, or Calibri fonts accepted.

PERFORMANCE INFORMATION	
Project Title	Williamina Fleming: Breaking Barriers with A Universe of Glass
Student Name(s)	Isabella Hardy
Division	Junior Division
Performance Runtime	9:50
Thesis	Williamina Fleming's unique ability to interpret astronomical photographs changed astronomy in nineteenth-century America and beyond, breaking barriers for scientists and for women.

PERFORMANCE OVERALL SCENARIO	
Story Setting(s)	Timeframe
The performance takes place at the Harvard Observatory, both outdoors and indoors.	Present Day (Narrator/Professor); 1910 (Williamina Fleming); mid-1930s(Annie Jump Cannon); Present Day (Narrator/Professor)
Story Synopsis	
A modern-day Harvard professor introduces the astronomer Williamina Fleming, whose many discoveries include the Horsehead Nebula. Fleming herself discusses her life and work, which involved studying and interpreting the photographic images taken through telescopes while making notes on the glass plates. Her colleague and friend Annie Jump Cannon, who outlived Fleming by decades and wrote her obituary, discusses Fleming's legacy, including the many stars and other objects she discovered. The professor returns to the modern day to discuss the fate of the glass photographic plates and Fleming's historical impact on the study of astronomy, particularly for women.	

CHARACTERS		
Character	Performer	Description/background for the character
Professor	Isabella Hardy	This character is loosely based on Dr. Lindsay Smith, the current Curator of Astronomical Photographs. She provides a framework for the performance. She also represents the many women who work in astronomy today.
Williamina Fleming	Isabella Hardy	Williamina Fleming was a Scottish immigrant who became an important late nineteenth/early twentieth century astronomer at Harvard. Her story is the focus of the project. The character in the performance uses a Scottish brogue, and several of her lines come directly from Fleming's journal and article writing

		[these appear in bold text in the template]. She is speaking from 1910, because Fleming died in 1911, and she had already made many of her major discoveries.
Annie Jump Cannon	Isabella Hardy	Since Fleming died young, Cannon, who outlived her and knew her well, explains Fleming's death and legacy. She is speaking from the mid-1930s, when she was in her late sixties, so she is portrayed as older, but she always had hearing loss even as a young woman, so she speaks loudly.
Professor	Isabella Hardy	The professor returns the story to the present day and to the impact of Fleming as well as the fate of the glass plates.

OVERALL STAGE SETTING

Describe the Stage(s) of the Performance
Add Photo of Stage (if possible)

Color Use Scheme

The stage is dominated by a large replica telescope on a tripod. At the eyepiece is a wooden chair for an observer. In front of these is a wooden table.



Background Design

A blue backdrop cloth with glow-in-the-dark stars is used to represent the night sky outdoors and also the sky that would be visible through the open doors for the telescope.

Props

On the table are a 1925 copy of Forest Ray Moulton's *An Introduction to Astronomy*, along with the tools of Williamina Fleming and her colleagues: glass photographic plates (reproductions, images were replicated by tracing copies of original plates from Harvard archives), "flyspanker" (used to help computers compare star images; this reproduction is based on photographs of the original items), open log book, inkwell and dip pen, glass magnifier, glass prism and its box, wooden ruler, and copies of spectra charts used by computers in the workroom of the astrophotographic building. In the photograph, "Fleming" holds one of the glass plates and the flyspanker.

COSTUMES & PROPS BY SCENE

Please add or remove costume & props by scene as needed. This is only a template.

Scene # 1	This scene takes place at the Harvard Observatory in the present-day, at night in the wintertime, beginning outdoors and moving indoors, as the audience takes a “tour.”	
Costume(s) Visual(s) or Costume(s) Description(s)	Set Design & Props	
<p>Costume: Portraying a professor leading a tour, Isabella Hardy wears a black wool winter coat and crimson (Harvard color) wool scarf. [This costume is worn by the dress form in the photo. The dress form is not used in performance]. Under the coat, she wears Fleming’s costume, which includes the base costume: a cream button-down blouse worn over a corset, long gray wool skirt, and brown leather boots.</p>	Background Design	The Harvard telescope and starry night sky backdrop piece are visible.
	Props	The props for the overall stage setting (as in photograph) are visible but not used in this scene.

COSTUMES & PROPS BY SCENE

Scene # 2	This scene takes place inside the Observatory, in Williamina Fleming’s workroom, 1910.	
Costume(s) Visual(s) or Costume(s) Description(s) If costumes and props remain the same, write “same as scene # in the boxes below”	Set Design & Props	
<p>Costume: Portraying Williamina Fleming, Isabella Hardy wears a plum-colored velvet jacket over a cream button-down blouse over a corset to create a proper period silhouette. A black ribbon is tied around the neck to replicate the black bow tie Fleming is seen wearing in many period photographs. She also wears a long gray wool skirt, and brown leather boots. [Worn by student in the photo]</p>	Background Design	The Harvard telescope and starry night sky backdrop piece are visible, as is the wooden chair. The wooden table is used by Fleming.
	Props	The main stage props are all visible. Fleming uses the glass photographic plates (reproductions, images were replicated by tracing copies of original plates from Harvard archives), “flyspanker” (used to help computers compare star images; this reproduction was based on photographs of original), log book, inkwell and dip pen, magnifier, glass prism, wooden ruler, and copies of spectra charts used by computers.

COSTUMES & PROPS BY SCENE

Scene # 3	This scene takes place at the Harvard Observatory in the mid-1930s	
Costume(s) Visual(s) or Costume(s) Description(s) If costumes and props remain the same, write "same as scene # in the boxes below"	Set Design & Props	
<p>Costume: Portraying Annie Jump Cannon, Isabella Hardy wears a cream button-down blouse, long gray wool skirt, brown leather boots. green cardigan, and string of (plastic) pearls. Photographs of Cannon later in her life often depict her wearing a cardigan and pearls [cardigan hangs on the chair in the photo].</p>	Background Design	The Harvard telescope and starry night sky backdrop piece are visible, as is the wooden chair. The telescope, wooden table, and wooden chair are used by Cannon.
	Props	The main stage props are all visible. Cannon uses the book, a 1925 copy of Forest Ray Moulton's <i>An Introduction to Astronomy</i> , which mentions some of the work and discoveries at Harvard.

COSTUMES & PROPS BY SCENE

Scene # 4	This scene takes place at the Harvard Observatory, back in the present.	
Costume(s) Visual(s) or Costume(s) Description(s) If costumes and props remain the same, write "same as scene # in the boxes below"	Set Design & Props	
<p>Costume: Portraying the Professor again, Isabella Hardy again wears the black wool winter coat and crimson (Harvard color) wool scarf [worn by the dress form in the photo] over the base costume: a cream button-down blouse, long gray wool skirt, and brown leather boots.</p> <p>[Her appearance is the same as in scene #1]</p>	Background Design	The Harvard telescope and starry night sky backdrop piece are visible, as is the wooden chair. The wooden table is used by the Professor.
	Props	The main stage props are all visible. The professor uses the glass photographic plates (reproductions, images were replicated by tracing copies of original plates from Harvard archives).

PERFORMANCE SCRIPT BY SCENES

Please add or remove scene pages as needed. This is only a template.

SCENE 1 - SCENARIO

Purpose of the Scene		Key Elements	
<p>This scene creates a “frame” for the performance by setting the scene at Harvard. It introduces Williamina Fleming and provides background on her early life. It explains how she became employed at Harvard and began her work in astronomy.</p>	Setting	Outside the Harvard Observatory, moving into the workroom	
	Timeframe	Present Day, in the winter, when the Horsehead Nebula is over eastern North America	
	Characters	Narrator, loosely based upon Dr. Lindsay Smith, Harvard’s current Curator of Astronomical Photographs	
Summary of the Scene			
<p>A Harvard professor leads a tour group (the audience) at the Observatory, while reciting Walt Whitman’s poem “When I Heard the Learn’d Astronomer.” She points out the Horsehead Nebula, which was discovered by Williamina Fleming, and leads the group inside the building, where she explains Fleming’s early history up until her employment at the Observatory and points out that she was the first female to have a title at Harvard.</p>			

DIALOGUE - SCENE 1

Character & Action	Dialogue
<p>Character (Actor Name) <i>(Action & movement direction)</i></p>	(Spoken words)
<p>Character (Actor) <i>Professor</i> Beginning stage right, the Professor (Isabella Hardy) recites the poem, with special emphasis on the pronoun “he,” to stress that the 19th-century world of astronomy was a male one. She makes a skyward gesture at the last line, with her hand raised as she finishes reciting.</p> <p>She very slowly lowers her arm and begins walking toward stage right,</p>	<p>When I heard the learn’d astronomer, When the proofs, the figures, were ranged in columns before me, When I was shown the charts and diagrams, to add, divide, and measure them, When I sitting heard the astronomer where he lectured with much applause in the lecture-room, How soon unaccountable I became tired and sick, Till rising and gliding out I wander’d off by myself, In the mystical moist night-air, and from time to time, Look’d up in perfect silence at the stars.</p> <p>Overhead, is the Horsehead Nebula, which, in 1888, twenty years after American poet Walt Whitman wrote that lovely poem, was discovered by a woman named Williamina Fleming. Fleming’s unique ability to interpret astronomical photographs changed astronomy in</p>

suggesting she is entering the Observatory workroom. She takes up a position on stage right, beside the table.

She makes an expansive arm movement to stress the long name of Edward Charles Pickering Fleming.

She gestures overhead with both hands, her fingers extended, as she says, "mapping the sky" and then gestures toward the telescope as she describes the methods of the astronomers at Harvard.

As she finishes speaking, she turns and removes her coat and scarf to reveal Fleming's costume underneath. She hangs the coat and scarf on the chair back, and when she turns, she has become Williamina Fleming.

nineteenth-century America and beyond, breaking barriers for scientists and for women. Fleming was born in 1857, in Dundee, Scotland, to Mary Walker and Robert Stevens, a carver and gilder. When she was 20 years old, she married James Orr Fleming, a widower. She taught school for a short time, and one year later, they immigrated to America.

Soon after they arrived, she was abandoned by her husband. Desperate for money, she became the maid for Professor Edward Charles Pickering, Director here at Harvard Observatory. He was an early supporter of women as university employees. His wife noticed how intelligent and capable Fleming was and suggested that she be hired to work at the observatory. After giving birth to her son, whom she named Edward Charles Pickering Fleming in honor of Professor Pickering and his support, she began the work of mapping the sky.

Their methods were a little different than our modern ones: instead of using computers, they analyzed photographs taken through telescopes.

She was the first woman to have a title here at Harvard.

SCENE 2 - SCENARIO

Purpose of the Scene	Key Elements	
This scene provides Fleming's point of view in her own voice and takes place the year before she died suddenly of pneumonia. She describes her regular tasks and duties at the Observatory, as well as some of her discoveries, opportunities, and challenges.	Setting	Inside the workroom of the Observatory
	Timeframe	1910
	Characters	Williamina Fleming

Summary of the Scene

Fleming describes the work performed by herself and the other female computers, as well as her duties as Curator of Astronomical Photographs. She points out how women were paid less than men but were treated with respect by male colleagues, including Director Pickering. She explains the process of analyzing the photographs and discusses some of her honors and discoveries. She also mentions notable women with whom she worked.

DIALOGUE - SCENE 2

Character & Action	Dialogue
<p>Character (Actor Name) <i>(Action & movement direction)</i></p>	(Spoken words)
<p>Character (Actor) <i>Williamina Fleming</i> Williamina Fleming (Isabella Hardy), speaks using a distinct Scottish brogue. She stands very straight behind the table to imitate the posture demonstrated by Fleming in many period photographs. From here, she gestures to the telescope and then picks up one plate and the pen. She mimes writing on the plate.</p> <p>While she describes the process, Fleming gestures to the room, and then she lifts the pen, the "flyspanker," the ruler, and the magnifier in turn to illustrate each task as she describes it. [The phrases in bold are quoted verbatim from several different entries from her journal.]</p>	<p>Hello there, I am the Curator of Astronomical Photographs, Mina Fleming.</p> <p>Astronomers use cameras to take images of small sections of the sky through telescopes like the one here at Harvard as well those in places like Peru. These thin glass plates are then sent here to us, and we use a pen to record all the stars on that plate.</p> <p>Here in the astrophotographic building of the observatory, a team of women, including myself, are engaged in the care of the photographs. We identify, examine, and measure; reduce those measurements; and prepare the results for the printer. As curator here, I supervise the computers, write letters, offer advice, and prepare publications. These responsibilities consume so much of my time that little is left for my own research. Even though I do not make observations with the telescopes, by interpreting the images on these glass plates, I have opportunities to make discoveries and to understand the universe.</p>

She mimes writing notes on the plates and in the logbook as she continues speaking.

Fleming holds up three fingers, then one, to show the difference between salaries of men and women.

She puts her hand on her hip and makes an exasperated gesture.

Her tone is sarcastic, but not bitter. Her accent still conveys brogue, as she clearly says, "canna be," for "cannot be."

Fleming's tone changes to a kindlier and more understanding one, showing her appreciation of Pickering despite her frustrations. [The text in bold is from an article she published in 1893 in *Astronomy and Astrophysics*.]

As she slowly begins taking the prism out of its protective box, Fleming carefully recites the names of these societies to which she belongs. She is very careful with the accent on the French society's name.

Fleming demonstrates the use of the prism with the glass plates.

She displays the spectra charts that are lying on the table, and her tone is modest.

There is no end to the work on hand in the photographic and photometric departments.

The university gets plenty of work from a staff of women, as three of us cost the same as one man. Six days a week, I am here at the Observatory, generally from 9 in the morning until 6 in the evening.

Sometimes I am tempted to give up and let the Director try someone else, or some of the men to do my work in order to have him really find out what he is getting from me for such a small salary, while running a household and raising my son, who is thankfully now a successful mining engineer in Chile. **I am told that my services are very valuable to the observatory, but when I compare the compensation with that received by women elsewhere, I feel that my work cannot be of much account.**

That is not to say the men here are unkind. In fact, we are **graciously treated with the greatest courtesy, encouragement, and assistance**. I am grateful for the many opportunities Director Pickering has provided for me, and his support has aided me in many of my accomplishments.

Just four years ago, in 1906, I was made an honorary member of the Royal Astronomical Society of London, and I am also a member of the Astronomical and Astrophysical Society of America and the Societe Astronomique de France.

Professor Pickering's willingness to train and employ women has allowed me to make many wonderful discoveries. When I first started here, he had just begun using prisms with the photographs to indicate the spectra of stars.

The spectra are unique to each star, and I have been privileged to study hundreds of variable stars.

As she puts the prism away in its box, Fleming also consults her plates for reference on the star she is describing.

As she describes Draper and her contributions, Fleming gestures to the plates on the table, and then gestures behind her to indicate the telescope.

Fleming picks up one of the charts on the table as she speaks of Leavitt in an appreciative tone.

While Fleming starts walking back toward the chair, she is speaking warmly of her friend Annie Jump Cannon.

As she finishes speaking, she turns around, removes her jacket and ribbon tie, and hangs them on the chair. She removes the cardigan from the chair back and puts it on; she then takes the “pearls” from her pocket and puts them on to “become” Cannon. She sits in the chair and begins peering through the telescope.

Not long ago, Professor Pickering and Professor Russell of Princeton were curious about the star 40 Eridani B and its spectrum. I confirmed that it was the first documented white dwarf, a type of star I have described in a recent paper.

There are many other women whose contributions have added to the study of astronomy here at Harvard. The Draper Catalogue of Photographs and our telescope are sponsored by Mrs. Anna Draper, in honor of her late husband.

Miss Henrietta Leavitt, one of the many women under my supervision, has created a formula to determine the distances of stars. Using Miss Leavitt’s formula has helped us understand more about our universe.

Then there is also Miss Cannon, who has already discovered one spectroscopic binary, a new kind of star, and I hope she finds much more.

SCENE 3 - SCENARIO

Purpose of the Scene	Key Elements	
This scene provides information about Fleming's death and legacy, as well as her citizenship and discoveries	Setting	Telescope room at Harvard
	Timeframe	@mid-1930s
	Characters	Annie Jump Cannon
Summary of the Scene		
Annie Jump Cannon explains her own role at the Observatory, which included writing obituaries, like Fleming's. She explains Fleming's historic discoveries and her honors, as well as her desire to break barriers by being recognized as an astronomer.		

DIALOGUE - SCENE 3

Character & Action	Dialogue
<p>Character (Actor Name) <i>(Action & movement direction)</i> Annie Jump Cannon Cannon (Isabella Hardy) is sitting in the chair, looking through the eyepiece of the telescope.</p> <p>She speaks very loudly, especially as she gives the date she began at the Observatory, stressing her age. By including "forty years," she is also indicating that the time frame is the mid-1930s. Her tone is fond and appreciative when she mentions Fleming.</p> <p>Cannon stands and walks to the stage right side of the table. She picks up the 1925 Astronomy book that includes many Harvard discoveries and opens it briefly as she mentions Fleming's accomplishments, some of which are included in this text. Fleming's friends often called her "Mina."</p>	<p>(Spoken words)</p> <p>Good Evening! I am Miss Annie Jump Cannon, one of the many women computers here at Harvard Observatory. Pardon me, I am a little hard of hearing. I've been here since 1895 and I have worked with many amazing women. They have inspired me in the discoveries I have made over the past forty years and the honors I have received. One of my honors has been writing the obituaries for many of my accomplished colleagues including Director Pickering, Miss Henrietta Leavitt, and, of course, Miss Fleming.</p> <p>In her short life, before her untimely death in 1911, Mina made many wonderful discoveries that revolutionized astronomy, including ten new stars and more than 300 variable stars because of the presence of bright lines in their spectra. She classified the spectra of 10,351 stars in her 30 years of service, years that saw many barriers broken for women in astronomy.</p>

Cannon's tone is admiring and enthusiastic when describing the honors from Wellesley, and sympathetic when mentioning Fleming's inability to have a formal education.

Cannon's gestures stress her words, as she lowers her hand on the words "small child," then rubs her own right arm when describing Fleming's injury.

As she gestures for emphasis, Cannon is clearly proud of her friend.

She turns and removes the sweater, hanging it on the chair. She puts on the winter coat and scarf to change back into the role of the Professor.

For her many achievements, Mina was appointed an honorary Fellow at my Alma mater, Wellesley, although she never attended college.

Shortly before her death, The Astronomical Society of Mexico presented her with a gold medal for her discovery of new stars. She was a dedicated, hard worker all her life, even though she had health issues ever since she was a small child. Because of her work at the observatory, her right arm was often sore, and she worked long hours even when ill. Her job was important to her, and she fought for women to be recognized for their work in Astronomy.

In 1907, on her application for American citizenship, she listed her job as ASTRONOMER. Not only did she break barriers for herself, but also for all women in the sciences and society.

SCENE 4 - SCENARIO

Purpose of the Scene	Key Elements	
This scene closes the performance and describes the flooding of the building where the photographic plates are stored. It also describes the role of women in astronomy today and emphasizes the theme.	Setting	Telescope room at Harvard
	Timeframe	Present Day
	Characters	Professor
Summary of the Scene		
The professor explains the end of the Harvard human computer program but stresses that the plates are still important as historical artifacts and as tools. She describes the flood in 2016 that removed some of the annotations on the plates and looks at the impact and legacy of Fleming's work. Fleming's gravestone is described in closing.		

DIALOGUE - SCENE 4

Character & Action	Dialogue
<p>Character (Actor Name) <i>(Action & movement direction)</i> Professor</p> <p>The Professor (Isabella Hardy) turns and stands in front of the chair, where she gestures toward the telescope.</p> <p>She first gestures enthusiastically toward the plates, and then she raises one arm heavenward, as if tracing the paths of stars. Her tone is upbeat.</p> <p>The Professor's tone becomes quiet and distressed and she picks up one of the plates. Her tone remains hushed and concerned as she mimes water washing over the plate to erase the marks that are visible there. She replaces the plate and puts her hand protectively over it.</p>	<p>(Spoken words)</p> <p>Harvard continued to employ women to map the night sky until the second world war when they struggled to find staff, male or female. Today, light pollution prevents the kind of observations once made here at Harvard.</p> <p>However, the plates are still being studied to help us understand the changing heavens, as they are the only record we have of the night sky a hundred years ago.</p> <p>In January of 2016, a pipe burst, flooding the building in which the photographic plates are housed. Volunteers worked many hours to recover the plates and repair the damage done by the dirty water. Sadly, although the plates did not suffer from mold or breakage, the flood erased some of the marks left by the Harvard human computers, including Williamina Fleming.</p>

The Professor's tone shifts to an appreciative one when mentioning Cannon and Leavitt, and her volume returns to a normal level. Her facial expression shows frustration at Fleming's lack of recognition.

The Professor puts her hand on her chest in gratitude, and then makes a sweeping, wide-arm gesture toward the sky.

She gestures stage right on "social" and left on "economic," and then energetically center stage as she lists the discoveries. She then gestures to the sky on "Horsehead," mimicking her position from the beginning of the performance.

As she describes Fleming's grave, the Professor gestures toward the cemetery, and then she makes a sweeping gesture, as if the word "astronomer" is written on the sky. Then she carefully lifts one plate, holds it skyward, and looks up through it at the sky with a wistful expression as she says, "her beloved universe of glass."

She remains frozen in that pose to complete the performance.

While some of the women she trained and supervised, including Annie Jump Cannon and Henrietta Leavitt, have been rightly rewarded and recognized for their contributions to the study of astronomy, Fleming has not always received the recognition she deserves.

Her contributions continue to be invaluable to science, and to women like me, who are now free to study the universe.

While she broke social and economic barriers that kept women from positions in science and academia, she also broke barriers with her discoveries, including 10 previously unknown novae, 310 stars, the very first documented white dwarf star, and 59 gaseous nebulae, including the Horsehead.

Fleming, who was laid to rest in a cemetery near the Observatory, has a stone that reads ASTRONOMER, the title that she wanted and deserves, for the barriers she broke, and the discoveries she made with her beloved universe of glass.