The Story of Starlight:
Women Who Changed Our Understanding of the Universe

Lilianna Hug
Senior Division
Individual Performance
Process Paper: 497 words
June 2020

NHD PERFORMANCE SCRIPT COVER PAGE

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PERFORMANCE INFORMATION	
Project Title	The Story of Starlight: Women Who Changed Our Understanding of the Universe
Student Name(s)	Lilianna Hug
Division	Senior Individual Performance
Performance Runtime	9:49 min
Thesis	In the late 19th and early 20th centuries, the women computers of Harvard Observatory broke barriers in astronomy by making significant astronomical discoveries, and they also broke barriers in women's rights by working in a field where inequality was prevalent. Through their dedication, hard work, and intelligence, they prevailed against the social barriers of their time and paved the way for future women astronomers who pursued careers in astronomy.

PERFORMANCE OVERALL SCENARIO	
Story Setting(s)	Timeframe
My performance is set in modern times, as a planetarium presentation at the Charles Hayden Planetarium in Boston, MA. It also takes place in the early 20th century at the Harvard College Observatory in Cambridge, MA.	1930 - 2020 (broad)
Story Synopsis	
A modern day presenter at the Planetarium introduces the performance and provides background information on the women computers at Harvard Observatory. Scene changes and Annie Jump Cannon recalls her personal stories. Cannon shows the audience what kind of work the women computers were doing, and demonstrates with the glass plates. Cannon discusses the discoveries of her friend Miss Henrietta Leavitt, and also talks about the huge barriers facing the women computers during that time. Scene changes and Planetarium Presenter returns to discuss in detail the astronomical discoveries and the lasting historical impact of Annie Jump Cannon, Henrietta Leavitt, and Cecilia Payne-Gaposchkin. Planetarium Presenter closes the performance with descriptions of the barriers the women computers broke, their impact on modern women astronomers, as well as several key astronomical events that relate to their work.	

CHARACTERS		
Character	Performer	Description/background for the character
Charles Hayden Planetarium Presenter	Lilianna Hug	Wearing a blue jacket with a NASA patch on the front.
Annie Jump Cannon	Lilianna Hug	Wearing a 1930's style vintage belted floral printed dress with pearl necklace and pumps.

<table>
<tr><th colspan="3">OVERALL STAGE SETTING</th></tr>
<tr><th>Describe the Stage(s) of the Performance
Add Photo of Stage (if possible)</th><th colspan="2">Color Use Scheme</th></tr>
<tr><td rowspan="2">The Auditorium of the Charles Hayden Planetarium. (Photo depicts stage at conclusion of the performance, when the nebula banner has been rolled down to cover the Harvard Observatory sign and all of the stars have been turned on).
</td><td>Back-ground Design</td><td>A black curtain hangs between two tall poles, creating a backdrop 6 foot square. A cluster of 100 tiny LED lights fills the center of the black backdrop, depicting a star-filled sky. On the right side of the backdrop, also hanging from the pole, is a 4 foot long poster board with large black and white photos of Annie Jump Cannon, Henrietta Leavitt, and Cecilia Payne-Gaposchkin. On the left of the black backdrop is a sign that reads: "Charles Hayden Planetarium," listing the titles and schedule of the day's planetarium shows. In front of the backdrop is a table and chair.</td></tr>
<tr><td>Props</td><td>The table holds the following props:
❖ A "light lectern," a tool used by the women computers, is an angled wooden frame attached to a horizontal mirror, made to hold a glass plate. The lectern is a reproduction of the originals at Harvard that I saw while I was on my research trip.
❖ Replicas of glass plates on the lectern, made by printing digital copies of the plate images on sheets of overhead film and attaching to panes of glass.
❖ A "fly spanker" (a replica of one viewed at Harvard; a small piece of glass with twisted copper wire as the handle and black dots for the stars)</td></tr>
</table>

		❖ An enlarged image of stellar spectra, depicting bands about ten inches long. The spectra the computers were classifying were only about 1/8 to ¼ inch long, so for this prop I enlarged the image for audience visibility. ❖ A teacup ❖ A glass prism

COSTUMES & PROPS BY SCENE Please add or remove costume & props by scene as needed. This is only a template.		
Scene #	1	
Costume(s) Visual(s) or Costume(s) Description(s)	Set Design & Props	
As the Planetarium Presenter, I wear a blue jacket with a NASA patch over my costume for Annie Jump Cannon.	**Background Design**	The black backdrop has the stars (tiny LED lights) turned on just in a strip in the middle of the backdrop. A sign hanging off of the top pole is titled: “Charles Hayden Planetarium” and has a list of upcoming Planetarium shows. Both this sign and another board that has images of Annie Jump Cannon, Henrietta Leavitt, and Cecilia Payne-Gaposchkin hang on opposite sides of the black backdrop and slightly cover the backdrop.
	Props	No props are specifically used as the Planetarium Presenter. At the end of this scene, I do turn over the sign for Charles Hayden Planetarium at the end of the scene to signify a change in scene to Harvard Observatory and the early 20th century.

COSTUMES & PROPS BY SCENE		
Scene #	2	
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	
As Annie Jump Cannon, I wear a 1930’s style floral dress with a collar, pearl necklace, and pumps.	**Background Design**	The background is the same as in scene 1, except the sign on the left side of the backdrop

		now reads "Harvard Observatory" - and has images of many of the women computers, as well as an etching of Harvard Observatory, circa 1880.
	Props	In this scene I use the teacup, both glass plates, the fly spanker, the image of spectra, and the glass prism.

COSTUMES & PROPS BY SCENE		
Scene #	3	
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	
As the Planetarium Presenter again, I put the blue jacket back on.	**Background Design**	During this scene, I turn on the rest of the LED lights so that the entire backdrop is filled with stars. I also pull a ribbon and the 3' by 5' banner of a nebula rolls down.
	Props	During this scene, I slide back the board with images of Annie Cannon, Henrietta Leavitt, and Cecilia Payne-Gaposchkin to reveal two large lights that are blinking - which is a demonstration of the period luminosity relationship.

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	
The purpose of this scene is to establish the setting and provide background context which could not be done in a first person interpretation of Annie Jump Cannon. This scene sets up the rest of the performance.	**Setting**	Charles Hayden Planetarium
	Timeframe	2020
	Characters	Planetarium Presenter
Summary of the Scene		
The Planetarium Presenter describes what the presentation will include, provides background information on the development of photography and astronomical photography, and talks about the Harvard Observatory to set up the next scene with Annie Jump Cannon.		

DIALOGUE - SCENE 1	
Character & Action	**Dialogue**
Character (Actor Name) *(Action & movement direction)*	(Spoken words)
Planetarium Presenter:	Welcome to the Charles Hayden Planetarium! Before we begin our show, we ask that you please turn off your cellphones. If you need to leave, exits are on your left and right. Have you ever looked up at the night sky and wondered just how many stars are up there? In today's planetarium program, we are going to focus on a group of women in the early twentieth century who forever changed our understanding of astronomy by breaking barriers in our perceptions of the Universe. So lean back in your chairs and get comfortable as we tell the story of the stars.
(Pick up a glass plate from the light lectern and hold it up to the light).	In the 1840's and 50's, photography was a new idea. The earliest photographs were made on tin, but soon photographers found that glass was a better material. As the process was perfected, astronomers realized that photography offered many advantages for the study of stars. They could now continue their research during the day, and the long exposure times required for photography allowed

(Flip over the sign marked "Charles Hayden Planetarium" to reveal an etching of the Harvard Observatory, circa 1890, and a photograph of the team of women who worked at the Observatory).	faint stars not visible to the human eye to come into focus. A new world of possibilities was unveiled. In the 1880s, Edward Pickering, the director of the Harvard Observatory in Cambridge Massachusetts enacted a bold new program - his goal was to catalogue and classify the stars in the entire sky. Director Pickering saw the implications for huge amounts of data that could be collected with astronomical photography. Pickering was also a supporter of women's rights, so he hired a team of women to process the data on the photographic glass plates. These women were called **"computers"** and among them, several stand out, women who broke barriers that changed astronomy. Let me take you to 1930 to meet **Annie Jump Cannon**.

SCENE 2 - SCENARIO		
Purpose of the Scene	Key Elements	
The purpose of this scene is to present the majority of my information about the women computers at Harvard Observatory in a first person interpretation as one of the women computers.	**Setting**	Harvard Observatory
	Timeframe	1930
	Characters	Annie Jump Cannon
Summary of the Scene		
In this scene, Annie Jump Cannon tells the audience about her memory of her early interest in astronomy. Cannon also shows the audience the kind of work the women computers did, and demonstrates with the props on the table. She tells about one of her discoveries and her recognition all over the world for her classification system. Cannon includes another anecdote about her most interesting discovery - which is a direct quote from one of her radio broadcasts. Cannon also tells about the discovery of her friend Henrietta Leavitt, and describes the obstructions and barriers to women working in astronomy at that time, including information about a Harvard professor and medical doctor who wrote a book that argued women were unfit to attend college.		

DIALOGUE - SCENE 2	
Character & Action	**Dialogue**
Character (Actor Name) *(Action & movement direction)*	(Spoken words)
Annie Jump Cannon	

(Enter Annie Cannon. Annie Cannon is wearing a 1930's style floral dress with a collar, pearl necklace, and pumps).	
Annie Cannon sits down and holds the teacup and saucer. Speaks as an older woman with a New England accent. *Stand up on "first female."*	I remember when I was a little girl, my mother used to take me up to the roof of our small house, where we would sit for hours looking at the heavens and observing the stars. Those early experiences inspired me to pursue a career in astronomy, and I was fortunate to obtain a job at the Harvard Observatory in 1896, where I was the **first female** assistant ever commissioned to use a telescope, a task previously reserved as a man's work. During the day, along with the other women computers, I examined stars on the photographic plates.
(Pick up glass plate #1, which is a reproduction of an original glass plate that shows the stars: hold up to the audience). *(Pick up fly spanker, a 1 by 2 inch glass segment with a twisted wire handle; the glass depicts 12 black dots representing stars of decreasing magnitude).*	The majority of the glass plates here at Harvard are negatives of the stars, which means the stars appear as black dots against a white background. One of the primary jobs that has been undertaken here at the Observatory is determining the magnitudes of stars on each plate. We call this tool a "fly spanker" because it is "too small to do a fly much damage." These fly spankers have stars of each magnitude, labeled 1 to 12. To find the magnitude of a star, simply compare the stars on the fly spanker to the star on the plate and record the number.
(Hold up glass prism and image showing several different spectra and refer to the spectral lines on the image).	We use a different type of glass plate to study the spectra of stars. When you put a glass prism inside a telescope, starlight appears as bands of light, separated by thin and thick black spectral lines.
(Sit down on chair again. Refer to 2nd glass plate, showing the spectra of many stars).	My particular area of study is examining the spectra of the brightest southern stars, so that the Observatory will have a record of stars across the entire sky. I recently examined this plate. To begin, I

(Demonstrate how the light lectern works).	place the plate on this light lectern, near a window, so that sunlight is reflected to light the plate from behind. There are hundreds of spectra on every photographic plate, and most of them are merely an 1/8 to a 1/4 of an inch long! In 1901, I developed a new system for classifying these stellar spectra, based on the different categories of spectral lines. This work contributed to the realization that these spectral lines reveal the temperature of the star, and may also identify the different elements present. My classification system has recently been adopted as the standard **all over the world** for classifying stellar spectra.
(Stand up, walk to stage left). *(Use hands to pantomime looking through a telescope. NOTE: words in quotation marks are taken directly from a radio broadcast AJC gave in 1941).*	People often ask me what my most interesting discovery has been. "Perhaps the most exciting was the discovery of a new star in the constellation Scorpio, while I was on my trip in Peru. It was something of a thrill to photograph its changing spectra night by night in that transparent Arequipa sky, and to realize that its light had been travelling about **thirty thousand years** to reach us on Earth."
(Walk to stage center, in front of the backdrop, and refer to the image of Henrietta Leavitt on the left).	Yes, we women computers made numerous scientific contributions. My dear friend Miss Henrietta Leavitt discovered what is called the "period-luminosity relationship," by comparing a single star on photographic plates taken at different times. Certain stars get brighter or dimmer in regular cycles, and Miss Leavitt realized that there is a correlation between the length of the "blink" and the brightness of a star.
(Walk to stage right).	Unfortunately, opportunities for women in science have been limited. Many of the women computers here at Harvard Observatory attended college, but many people believe that women should not receive higher education, let alone work in a scientific capacity. I remember when I began college, many people thought that higher

(Lower voice - to imitate Edward Clarke, the Harvard professor). *(Exit as Annie Cannon).*	education was detrimental to women's physical and mental health. A Harvard professor and medical doctor published a book in which he argued that women who attend college will "contract serious diseases, will experience mental instability, and won't even be able to have children." What a load of rubbish! Nevertheless, criticism and doubt continues among colleagues and the general public, and women computers are paid as little as 1/4 of what men receive! However, I know that our work has paved the way for future women astronomers. I truly hope that many women will continue to break the barrier of gender inequality to pursue degrees or careers in astronomy.

SCENE 3 - SCENARIO		
Purpose of the Scene	Key Elements	
The purpose of this scene is to wrap up the performance by describing the discoveries of Annie Jump Cannon, Henrietta Leavitt, and Cecilia Payne-Gaposchkin in detail, as well as put my topic in larger historical context by talking about the historical impacts of these women on astronomy and women's rights.	**Setting**	Charles Hayden Planetarium
	Timeframe	2020
	Characters	Planetarium Presenter
Summary of the Scene		
In this scene, the Planetarium Presenter talks about the discoveries of Annie Jump Cannon, Henrietta Leavitt, and Cecilia Payne-Gaposchkin in detail. The Planetarium Presenter also demonstrates the idea of Leavitt's discovery, the period-luminosity relationship, and describes in length the barriers facing these women and how they broke those barriers. In addition, I talk about the impacts of the women computers on women in astronomy in modern times, and also include information about the upcoming James L Webb Telescope, scheduled to be launched in 2021.		

DIALOGUE - SCENE 3	
Character & Action	**Dialogue**
Character (Actor Name) *(Action & movement direction)*	(Spoken words)
Planetarium Presenter *(Resume role of planetarium person; put on the jacket with NASA patch; Resume normal voice. Walk forward.)*	Now let's put some of these astonishing accomplishments into perspective. In the 45 years Cannon worked at the Observatory, she classified over 417,000 stellar spectra and discovered more than

(Refer to image of Annie Cannon.)	300 variable stars. In 1925, Annie Jump Cannon was the **first** woman to receive an honorary doctorate degree from Oxford University for her dedicated work in astronomy, but it wasn't until 1938, after she had worked 42 years at the Observatory, that Harvard officially recognized Miss Cannon as an astronomer and member of the Astronomy department.
(Refer to image of Cecilia Payne Gaposchkin).	Many other women from the Observatory also made significant contributions to modern astronomy. Cecilia Payne-Gaposchkin, the first **person** awarded a PhD in astronomy at Harvard, discovered evidence that hydrogen was about a **million times more prevalent** in stars than on Earth. At the time, many male astronomers discredited her work, but five years later, prominent astronomers admitted her findings were indeed correct, and she was recognized for discovering this remarkable property of stars.
(Refer to image of Henrietta Leavitt). *(Slide back images of women about 6 inches to reveal a pair of blinking stars on the black backdrop – a demonstration of Leavitt's discovery).*	Henrietta Leavitt's discovery of the period luminosity relationship also had profound impacts on astronomical knowledge. Let me explain. Imagine you are an astronomer. Looking up at the sky on a clear night, you observe two stars, which appear to have the same brightness. It's very unlikely that the stars are actually next to each other in space, but how do you figure out which star is farther away? Henrietta Leavitt realized that the slower some variable stars blink, the brighter they **actually** are. Thus, if you see one star blinking slower, you know that star is the one that is farther away. You can also use this information to compare the two stars and conclude that one star is, say, two times closer to Earth than the other star.
(Walk forward, stage center).	Henrietta Leavitt's amazing discovery, now referred to as "Leavitt's Law," transformed astronomy and proved to be the **yardstick by which astronomers could calculate distances in the universe.** In 1924 Edwin Hubble used Leavitt's Law to prove that

	there are multiple galaxies in the universe, which had been the ongoing astronomical debate of the decade. Hubble went on to discover that the universe is expanding, and many other astronomers used Leavitt's Law to determine other distances in space. Henrietta Leavitt thus helped people realize that our home galaxy, the Milky Way, is just one grain of sand among a whole **beach** of sand.
(Walk stage right, stand immediately next to the backdrop and Harvard Observatory sign).	The women computers of Harvard Observatory **broke barriers for women's role in science.** Many of these women had university degrees in astronomy or physics, and they were eager to contribute to scientific knowledge. They took the computing positions for far lower salaries than men were paid, and endured unequal treatment by male counterparts. Yet, as the first team of women working at an Observatory, they paved the way for future women in astronomy, as well as in other fields, demonstrating that women were more than capable in science. Modern women astronomers now acknowledge the remarkable achievements of these women and agree that they had lasting impacts on opportunities for women in astronomy. In the words of Dr. Blakesley Burkhart, a professor of astronomy at Rutgers University who studies interstellar magnetic turbulence, "Annie Jump Cannon directly or indirectly impacted every woman in astronomy."
	By the 1950's the women computers of Harvard Observatory had discovered more than **two thirds of all known variable stars at the time**. **They also found 10,000 new nebulae, and classified hundreds of thousands of stellar spectra.**
(On the words: "10,000 new nebulae," reach back and pull ribbon tying up a banner, which unfurls and reveals a large 3' by 5' ft poster of a stunning blue, red, and purple nebula, image courtesy of NASA).	This image was taken by the Hubble Space Telescope. In 2021, the James L. Webb Space Telescope will launch and is designed to see farther into the universe than ever before – replacing the Hubble telescope as the primary observatory of our age. The women of Harvard Observatory, as they persistently classified the

	stars on photographic glass plates, wouldn't have been able to imagine how far we have come in astronomy, and one can only wonder what these women, working on the frontiers of astronomy in their time, would have thought if they could have seen the images that can be captured today.
(On the word "expanded," use remote control to suddenly illuminate 200 more tiny LED lights, adding to the original lights in the center and filling the entire black backdrop with lights, to visually highlight the women's expansion of astronomical knowledge).	These women **broke barriers in our understanding of astronomy,** accumulating evidence which clarified the composition, temperature, life cycle, and number of stars in the cosmos. The dedicated work of these women expanded the **known size** of the universe and everything in it.
	Annie Jump Cannon once said in a radio broadcast: "What is more appealing to the imagination than the fact that those dark lines, written in starlight, bring us messages as to <u>what</u> the stars are, <u>where</u> they are, and how they move along through space."
(Move to center forward).	Annie Jump Cannon, Henrietta Leavitt, Cecilia Payne-Gaposchkin, and the other female computers of Harvard Observatory charted the heavens and made groundbreaking discoveries. Not only did these women break barriers in astronomy, they also broke through the glass ceiling which had for so many years limited women in science as they catalogued a glass universe and analyzed the story of starlight.

Process Paper

Astronomy fascinates me. From a young age I've looked up at constellations and wondered what is beyond those far-away stars. This passion for astronomy led me to Dava Sobel's book, *The Glass Universe.* After reading the story of these unknown women at Harvard Observatory who cataloged the stars on glass photographic plates in the late nineteenth and early twentieth centuries, I was amazed and inspired to learn more.

I began my research by reading several key secondary sources, which provided overviews of the topic and introduced me to the groundbreaking astronomical discoveries these women computers made. To continue my research, I met with a research librarian at California University of Pennsylvania, who provided valuable assistance with research techniques and guided me to key databases where I found further primary resources.

In February, I had the opportunity to explore Annie Jump Cannon's personal papers in the Pusey Library at Harvard University in Cambridge, Massachusetts. It took my research to a new level to see the handwritten journals, speeches, and scrapbooks she assembled, now preserved in 35 archival boxes of the Annie Jump Cannon Collection. This experience was incredibly inspiring, and I loved this chance to learn more about Cannon through documents that demonstrate her contributions to astronomy and the barriers she overcame.

Also on that research trip, I visited "Observatory Hill," where the women computers worked and where the glass plates (astronomical photographs on glass) are currently stored. The Curator of the Astronomical Plates Collection, Lindsay Smith-Zrull, whom I previously interviewed over the phone, provided a tour of the photographic glass plate stacks. All three floors of the building are crammed with filing cabinets, each containing about 3,000 glass plates. I was able to examine many glass plates and actual tools the women used, such as "fly spankers" and light lecterns. Viewing the original glass plates and reading the primary sources in the Annie Jump Cannon Papers are memorable highlights of my NHD research this year. I also enjoyed speaking with Rutgers University professor Dr. Blakesley Burkhart, the 2019 recipient of the Annie Jump Cannon award who confirmed the enduring legacy of these early computers.

Competing in the performance category provides a way for the audience to connect with history in a way not accessible through reading a textbook. My previous experiences portraying historical figures in the performance category have convinced me that performance allows history to come alive.

The women computers at Harvard Observatory exemplify this year's theme. These women computers broke barriers in women's rights as well as in astronomy. Annie Jump Cannon developed a classification system for stellar spectra that became the international standard, and Henrietta Leavitt discovered a way to measure distances in the universe. Cecilia Payne-Gaposchkin discovered that hydrogen was a main component of stars. What fascinates me is that these women prevailed against the social barriers of their time, and through their intelligence, hard work, and dedication, paved the way for future women computers and astronomers who pursued careers in astronomy.

Annotated Bibliography

Primary Sources:

"Annie Jump Cannon with plate." Undated photograph.

I used this undated photograph of Annie Jump Cannon as a prop and reference in my performance. I wanted the audience to have a visual material during my performance, and including images of the three women that I highlight in my performance allows the audience to empathize with these women and their accomplishments. I accessed this image through the Google Drive folder that Ms. Smith-Zrull (Curator of Astronomical Photographs at Harvard) sent me before our interview.

"a27014." Bloemfontein, South Africa, October 27, 1949. Astronomical Plates Collection. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA. http://dasch.rc.fas.harvard.edu/showplate.php?series=a&plateNumber=27014 (accessed February 21, 2020).

I used this glass plate in my performance to give the audience a visual of what the majority of glass plates at Harvard look like: negative photographs of black stars on a white background. These plates were used to determine the magnitude of the stars, as well as to find variable stars. This image is printed on a clear overhead sheet, and then put onto a plate of glass, so that it is a close replica of the real glass plates at Harvard. I accessed this online through Project DASCH, which is the glass plate digitization project currently in process at Harvard photographic plate stacks.

Armstrong, Henry. “Obituary: Mrs. Hertha Ayrton.” *Nature* 112, (1923): 800 – 801. https://www.nature.com/articles/112800a0 (accessed April 3, 2020).

Mrs. Ayrton was an electrical engineer and a physicist – and so her obituary was published in this issue of *Nature* journal, but the author exhibits a blatant disrespect for Mrs. Ayrton that verges on misogyny. When the author eventually got around to writing about Mrs. Ayrton herself, he mentioned in passing that she worked in science, and that she even was admitted to the Royal Society – a significant honor and recognition of Mrs. Ayrton’s scientific work, but the author thought that “they were ill advised” to admit Mrs. Ayrton. Armstrong goes on to say that he thought that his colleague Mr. Ayrton should have married a “humdrum” woman, one who was “useful” but knew her place, and then Mr. Ayrton would have led a “longer and a happier life and done far more effective work, I believe.” In summary, this source was very important as a counterargument – this is a demonstration of how even in the 1920’s people were opposed to women who worked in science and largely ignored their significant contributions. In addition to Edward Clarke’s book on women’s education, this source provided evidence for the tremendous barriers the women at Harvard Observatory were facing.

Bailey, Solon I. *The History and Work of Harvard Observatory, 1839-1927.* New York: McGraw-Hill Book Company, 1931.

This book covers the history of the Harvard Observatory and biographies of the directors of the Observatory, including Edward Pickering and Harlow Shapley, as well as information on the beginnings of astronomical photography and spectroscopy. This also discussed the discoveries of the women computers, particularly the period-luminosity relationship Miss Leavitt discovered. Solon Bailey, the author, wrote from first hand knowledge, since he had been involved for a long time as the director of Harvard’s telescope in Peru, and later as a senior staff member at the Cambridge Observatory.

Bailey, Solon I. "Henrietta Swan Leavitt." *Popular Astronomy* 30, no. 4 (April 1922).

Solon Bailey, a professor and astronomer at Harvard Observatory, wrote this article about Henrietta Leavitt after her death. Bailey summarized Leavitt's life, and explained her accomplishments. This document gave me a good understanding of what contemporaries and colleagues thought of Miss Leavitt's discovery and her work at the Observatory.

"Brainy Boston Women Learn Sky's Profoundest Secrets." *The Boston Sunday Journal*, July 10, 1904. Annie Jump Cannon Papers. Pusey Library, Harvard University, Cambridge, MA.

Annie Jump Cannon included this newspaper article in her personal scrapbook, which I accessed in the Annie Jump Cannon Papers at the Harvard Archives. The article is broken down into little sections, which have apt titles such as: "Miss Cannon's Catalogues" and "All By Women." This article allowed me to understand how Cannon's contemporaries viewed the work of the Harvard Observatory computers. Annie Cannon saved hundreds of newspaper articles in her papers and scrapbooks, which made me realize how esteemed Cannon was at the time, even if she is less widely known to many people today.

"b40431." Arequipa, Peru, June 14, 1909. Astronomical Plates Collection. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA. http://dasch.rc.fas.harvard.edu/showplate.php?series=b&plateNumber=40431 (accessed February 21, 2020).

I used this glass plate in my performance to demonstrate how the women computers examined the glass plates that show the spectra of stars. This plate image has markings made by Annie Jump Cannon as she classified the types of spectra and was taken from Harvard's telescope in Arequipa, Peru, where most of the plates Cannon classified were photographed. I accessed this online though the searchable database on Project DASCH.

Cannon, Annie Jump. “Astronomy for Women.” Speech, Century of Progress Exposition, Hall of Sciences, Chicago, 1933. Annie Jump Cannon Papers. Pusey Library, Harvard University, Cambridge, MA.

I found this speech by Annie Jump Cannon in the Annie Jump Cannon Papers at Harvard Archives. In the speech, Cannon describes the work women did at Harvard Observatory, specifically, the numbers of variable stars and nebulae that the women discovered, which gave me an idea of the scope of the women’s work, and which I include in my performance. This, along with some of Cannon's other speeches and broadcasts, also gave me a feel for her personality, which I tried to channel into my performance.

Cannon, Annie Jump. “The Story of Starlight.” Boston: WRUL, 1941. Annie Jump Cannon Papers. Pusey Library, Harvard University, Cambridge, MA.

I used the title of this radio broadcast: "The Story of Starlight" as the beginning of the title of my performance. I love how Annie Jump Cannon explained her work and the astronomy of the stars in an engaging way meant for a public audience in this broadcast. This also really gave me a feel for Cannon's humor and personality. This broadcast contained a quote I use in my performance about Cannon's most interesting or exciting discovery. I read the original typed manuscript, complete with Cannon’s handwritten notes, in the archived Annie Jump Cannon Papers at Harvard Archives.

Cannon, Annie Jump. “Astronomy for Women.” *Every Evening,* February 7, 1929. Annie Jump Cannon Papers. Pusey Library, Harvard University, Cambridge, MA.

This three-page radio broadcast by Annie Jump Cannon addressed the questions: "what possibilities are there for women in astronomy?" and "are they capable of ranking with men?" This gave me excellent insight into Cannon's opinions of the barriers facing women in astronomy, and how the women of Harvard Observatory were breaking many of those barriers. I accessed this in the Annie Jump Cannon Papers at Harvard Archives.

Cannon, Annie Jump. “All Sorts of Stars.” December 28, 1928. Annie Jump Cannon Papers. Pusey Library, Harvard University, Cambridge, MA.

This radio broadcast was one in a series of twelve broadcasts given by members of Harvard Observatory throughout 1928. Annie Jump Cannon gave several broadcasts, and this one provided another quote I use in my performance to demonstrate Cannon's love and fascination with astronomy and stellar spectra. I believe it’s important to include original quote in my performance, and I was very excited to read all these radio broadcasts in the Annie Jump Cannon Papers in the Harvard Archives.

Cannon, Annie Jump, and Edward C. Pickering. *Annals of the Astronomical Observatory of Harvard College: The Henry Draper Catalogue.* Vol. 91. Cambridge, MA: Harvard Observatory, 1918.

I used this book as an example of the Harvard Observatory Annals, which contained the Henry Draper Catalogue - a record of all the stellar spectra that had been classified the preceding year. The Harvard Observatory Annals spanned from 1852 to 1945. By 1918, the date of this volume, Annie Jump Cannon was the leading stellar spectra classifier, and one of her duties was to write the Henry Draper Catalogue, which was not a small task. The introduction to this was very helpful to me in getting a sense of Cannon's responsibilities, as well as the purpose of the Henry Draper Catalogue and how stars were classified at that time.

“Cecilia Payne-Gaposchkin at Harvard.” Undated photograph.

I used this image in my performance to give the audience a visual of Cecilia Payne-Gaposchkin. The three images that I include in my performance are important to the flow of performance; I am able to reference each photograph of women, which helps me to transition into speaking about each person’s accomplishments. This image is one that Lindsay Smith-Zrull, the Curator of Astronomical Plates Collection at Harvard, emailed to me in a google drive file.

Clarke, Edward H. *Sex in Education, or A Fair Chance for the Girls*. Boston: James R. Osgood and Company, 1873.

This book, written by a medical doctor and professor at Harvard, states his opinion as to why education for girls should be different than a boy's education. Clarke even gives “evidence” about how women who continued to attend college soon became weak, frail, and experienced many physical and mental illnesses. Clarke claims to have “treated” these women by telling them to take a vacation, after which they were all cured. I used this book to understand the counterarguments against the women working at Harvard Observatory. The author’s arguments helped provide an idea of the barriers the women needed to overcome to attend higher education, let alone pursue a career in science – which was a traditionally “male” field. I mention this book in my performance to demonstrate this key idea.

Fleming, Williamina Paton Stevens. “Journal of Williamina Paton Fleming,” 1900. Harvard Library Online Viewer. https://iiif.lib.harvard.edu/manifests/view/drs:3007384$1i (accessed December 13, 2019).

Williamina Fleming's personal journal over the course of a month in 1900 provided wonderful information for my performance. The journal documents the daily responsibilities of Mrs. Fleming, as well as her personal life and, perhaps most valuable of all, her thoughts on the place of women in astronomy and their salaries in comparison with men. It was deposited in the Observatory's time capsule the "Chest of 1900,” and it really gave me a sense of the barriers that the women computers were facing.

Fleming, Williamina. "A Field for Women's Work in Astronomy." *Astronomy and Astro-physics* 12 (1893). https://play.google.com/books/reader?id=MNBLAAAAYAAJ&printsec=frontcover&pg=GBS.PP5 (accessed November 12, 2019).

The journal *Astronomy and Astro-physics* published this speech that Mrs. Fleming gave in 1893 to the Congress of Astronomy and Astro-Physics in Chicago, in which she argued that astronomy is the perfect profession for women. She explained that at that time, 12 women were employed as "computers" at Harvard Observatory, and that they were proving themselves equal to men with their diligence and hard work. Mrs. Fleming addresses the issue of women working in science at the Harvard College Observatory, and concludes her speech with the powerful statement that astronomy is a field for women and that women can prove themselves equal or better than men in this field.

"General View of the Harvard Observatory." *Scientific American*, New York, 1887. Annie Jump Cannon Papers. Pusey Library, Harvard University, Cambridge, MA.

I used this illustration in my performance to show Harvard Observatory, as it looked in the late 19th century. Along with an image of the team of women computers, this illustration providing a transition from the Charles Hayden Planetarium and modern times to the character of Annie Jump Cannon in 1930. I accessed this in the Annie Jump Cannon Papers when I visited the Harvard Archives. Annie Cannon had this image pasted in one of her scrapbooks, where she liked to collect newspaper and magazine clippings.

"Harvard Honors 2 Women." *The New York Times*, January 18, 1938. Times Machine Online Archives. https://www.nytimes.com/1938/01/18/archives/harvard-honors-2-women-drs-cannon-and-gaposchkin-get-titles-in.html (accessed December 15, 2019).

This brief notice in The New York Times provides primary source documentation for one of the many barriers Annie Jump Cannon broke: official recognition by Harvard College as the William Cranch Bond Astronomer, as well as the appointment as the curator of astronomical photographs. Even though Annie Jump Cannon had been serving as the unofficial curator of astronomical photographs for 27 years, Harvard refused to actually appoint Cannon until 1938 because she was a woman. Ironically, Cannon's predecessor was a woman, Mrs. Williamina Fleming, but Harvard felt that Mrs. Fleming's position was "anomalous," and that they should not make a practice of appointing women.

"Henrietta Leavitt headshot." Undated photograph.

I used this photograph in my performance to give the audience a visual of Henrietta Leavitt. Along with the images of Annie Jump Cannon and Cecilia Payne-Gaposchkin, I used this image to transition into talking about Henrietta Leavitt's accomplishments. I accessed all these images in the online google drive file that Lindsay Smith-Zrull (Curator of Astronomical Plates Collection at Harvard Observatory) sent before our phone interview in November.

"Miss Cannon in King's Presence." *The Evening Journal*, July 2, 1925. Annie Jump Cannon Papers. Pusey Library, Harvard University, Cambridge, MA.

This article reports on Annie Jump Cannon's Oxford degree, which she received in 1925. Cannon was the first woman to receive an honorary doctorate degree from Oxford, and afterwards she met the King and Queen of England. This degree exemplifies just one of barriers that Cannon broke with her work at Harvard Observatory. It demonstrates how her contemporaries across the country and around the world viewed her contributions. I accessed this in the Annie Jump Cannon Papers at Harvard Archives where she proudly had this article pasted front and center in her scrapbook.

Payne-Gaposchkin, Cecilia, interview by Owen Gingerich, March 5, 1968, Harvard College Observatory. *Oral History Interviews*, American Institute of Physics. https://www.aip.org/history-programs/niels-bohr-library/oral-histories/4620 (accessed January 5, 2019).

This interview with Cecilia Payne-Gaposchkin was a fantastic resource. Payne-Gaposchkin described her experiences in her early life; I found the section where she talked about her time at Harvard and her research for her doctorate degree particularly helpful. She talked about Annie Cannon as well, since Cannon was the primary classifier of stellar spectra, and noted how kind Cannon was to her when she arrived at the Observatory. This interview helped me develop the section in my performance where I discuss Cecilia Payne-Gaposchkin.

Pickering, Edward C, and Henrietta Leavitt. *Periods of 25 Variable Stars in the Small Magellanic Cloud*. Harvard College Observatory Circulars, no. 173 (1912). http://articles.adsabs.harvard.edu/full/1912HarCi.173....1L (accessed December 1, 2019).

The Harvard Observatory Circulars were published for the quick distribution to the general public with news of scientific discoveries. This circular is where Henrietta Leavitt gives the evidence for her discovery of the period-luminosity relationship: that stellar luminosity has a direct connection with the length of a star's period. Though the circular was published under Edward Pickering's name, he wrote that it had been prepared by Miss Leavitt. Miss Leavitt notes in this circular that: "A remarkable relation between the brightness of these variable stars and the length of their periods will be noticed." This is the primary source that provided me with documentation for Leavitt's discovery.

Pickering, Edward C. "A Plan for Securing Observations of the Variable Stars." Cambridge, MA: John Wilson and Son University Press, 1882.

In this publication, Edward Pickering, the director of the Harvard Observatory declares his intent to use women as his observers. This document really helped me to understand the reason and motivation behind Pickering hiring a team of women, which would have been a very unusual act during that time period. Pickering was a supporter of women's rights and higher education for women, so he specifically hired women for jobs at the Observatory. He argued against contrary opinions (such as the book by Edward H. Clarke cited above) who claimed that working or going to college was damaging to women's mental and physical health.

Pickering, Edward C. *Fifty-First Annual Report of the Director of the Astronomical Observatory of Harvard College for the Year Ending September 30, 1896*. Cambridge, MA: Harvard University, 1896. https://babel.hathitrust.org/cgi/pt?id=njp.32101075380996&view=1up &seq=61 (accessed January 5, 2019).

In this annual report, Director Edward Pickering admits that "three or four times as many assistants" could be employed if the Observatory hired women instead of men. In Pickering's publication "A Plan for Securing Observations of the Variable Stars" he announces his intent to utilize women as computers. These two resources show the two reasons Pickering had for employing women: he was a supporter of women's rights and believed they would be able to do the work, yet he could also pay them less than men.

Reed, Helen Leah. "Women's Work at the Harvard Observatory," *New England Magazine, An Illustrated Monthly* 6, no. 2 (April, 1892). https://play.google.com/books/reader?id=-fNvtpQ4wj4C&hl=en&pg=GBS.PA165 (accessed November 11, 2019).

This magazine article discusses the women at the Harvard Observatory, and writes that they were the first ever team of trained women assistants at an astronomical observatory. In addition, this article claims that the women were paid the same amount as men assistants who did the same kind of work, which is interesting, because I found multiple other sources stating otherwise. This also gave a detailed description of the rooms where the computers worked, and provided a good point of view of the women of the time period.

"Spectra." *Henry Draper Memorial.* Astronomical Plates Collection. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA.

I hold this example of spectra bands in my performance to show what the spectra of a few stars look like. A lot of people don't realize that the women at Harvard were classifying spectra like this by looking at the black spectral lines, and the spectra were a quarter inch long or less on the glass plates. I accessed this through the online file folder the Curator of Astronomical Plates Collection, Lindsay Smith-Zrull, sent me before our phone interview.

United States Naval Observatory. *Report of the Superintendent of the United States Naval Observatory for the Fiscal Year Ending June 30, 1900.* Washington: Government Printing Office, 1900.

This report from the US Naval Observatory included tables of expenses from similar observatories, specifically, the Greenwich Observatory and the Harvard Observatory. This showed that the computers at Harvard received $600 annually. I was able to compare their pay to the salaries of computers at the other two observatories. At the US Naval Observatory, computers were paid about $1,200, which is backed up by this key quote from the report: "At Harvard computers receive an average of $600, less than the pay of any person in the United States Service. These computers are largely women, who can be got to work for next to nothing." This shows that although the women were able to work at the Observatory, they were still limited by the barrier of gender inequality and unfair pay.

"Women Astronomers in Van of Harvard's Achievements." *The New York Times,* December 20, 1936. Times Machine Online Archives. https://www.nytimes.com/1936/12/20/archives/women-astronomers-in-van-of-harvards-achievements-some-of-most.html (accessed December 15, 2019).
This 1936 article from the New York Times was an important "outsider" point of view of the computers' work. Interestingly, the article says that some of the "most important advances in astronomy are the independent contributions of women," and that Annie Jump Cannon's classification of stellar spectra is considered "one of the major contributions of all time to astronomical science." Before reading this key article, I had no idea that Cannon's contemporaries thought so highly of her achievements or recognized how valued her contributions were.

"Women Computers." 1918. Harvard College Observatory, Plate Stacks. Cambridge, MA.
This photograph shows many of the women computers at Harvard Observatory. I used this in my performance to show the team of women, all together, and to transition to the Annie Jump Cannon part of my performance. When I toured the plate stacks at Harvard Observatory, the Curator of the Astronomical Plates Collection, Lindsay Smith-Zrull, showed me this image and called it the "paper-doll" photograph, because of the panoramic view of the women all holding hands.

"12 Greatest U.S. Women Are Chosen." *Chicago Sunday Tribune*, May 6, 1923. Annie Jump Cannon Papers. Pusey Library, Harvard University, Cambridge, MA.
This short announcement was pasted in Annie Jump Cannon's scrapbook, which I accessed in the Annie Jump Cannon Papers in Harvard Archives. This article describes how the National League of Women Voters decided upon the 12 greatest American women who had contributed the most to "their several fields to the betterment of the world." Annie Jump Cannon was named as one of the 12 greatest women in America. This demonstrates how esteemed Miss Cannon was at the time, for her discoveries and work at the Harvard Observatory.

Secondary Sources

Bartusiak, Marcia, ed. *Archives of the Universe: 100 Discoveries that Transformed our Understanding of the Cosmos.* New York: Random House, 2004.

This book is a collection of primary source documents written by scientists who made groundbreaking discoveries throughout history, along with introductions and background information on each scientist and discovery. This book included several chapters on stellar spectroscopy, and showcased documents written about their discoveries by women who worked at Harvard Observatory, such as Annie Jump Cannon, Antonia Maury, and Cecelia Payne. The book helped pinpoint several good primary sources for further research.

Buchanan, Andrea J. "The Maid Who Mapped the Heavens." Narratively: Hidden History. https://narratively.com/the-maid-who-mapped-the-heavens/ (accessed November 21, 2019).

This article about Williamina Fleming was very engaging and informative. It provided a great understanding of the barriers that Mrs. Fleming and the women computers who followed in her footsteps broke. Mrs. Fleming was one of the first computers hired at the Harvard Observatory. She started out as Edward Pickering's maid, before he realized that she had a talent with numbers and astronomy. By the time Annie Cannon arrived at the Observatory, Mrs. Fleming was the Curator of Astronomical Photographs, so she had a large influence on Cannon.

Burkhart, Blakesley. Skype interview by Lilianna Hug. April 16, 2020.

To find out more about how modern astronomers view Annie Jump Cannon and the other women computer's accomplishments, I interviewed Dr. Burkhart, a professor at Rutgers University. In 2019 Dr. Burkhart won the Annie Jump Cannon Award in Astronomy for her work in plasma astrophysics. Dr. Burkhart told me: "Annie Jump

Cannon has had an impact directly or indirectly on every woman in astronomy." Because of Cannon's significant contributions to astronomy, many fields of astronomy today have equal numbers of women as men in the field, and in fact in many of those fields women outnumber men, which was made possible by some of Cannon's work as a woman in astronomy in the early 20th century. This interview was helpful because it was critical for me to have verification from a woman in astronomy today that the women computers of Harvard Observatory had lasting impacts on astronomy and opportunities for women.

Geiling, Natasha. "The Women Who Mapped the Universe and Still Couldn't Get Any Respect." Smithsonian Magazine. https://www.smithsonianmag.com/history/the-women-who-mapped-the-universe-and-still-couldnt-get-any-respect-9287444/ (accessed December 13, 2019).
This article not only discussed Annie Cannon and the women computers at the Observatory, but also Edward Pickering, his goal of cataloguing the entire sky, and his reasons for hiring women for computing work. This article brought up the point that although Pickering was a supporter of women's rights, by allowing them to do computing work, he inadvertently created a barrier for the women - since computing came to be defined as "women's work" and women computers were not usually able to be promoted to jobs as full fledged astronomers – Annie Jump Cannon was only called an "astronomer" by Harvard after she had worked 42 years at the Observatory.

Germiniani, Maicon. "The Great Carina Nebula." Astronomy Picture of the Day, NASA. https://apod.nasa.gov/apod/ap181227.html (accessed February 27, 2020).
I used this modern image in my performance, to give a visual of some of the accomplishments of the women computers. Since it was harder to demonstrate their other discoveries, showing a nebula seemed to be an appropriate choice. This image is of the Great Carina Nebula, which is 300 light years across and is one of our galaxy's largest star-forming regions.

Grier, David Alan. *When Computers Were Human*. Princeton: Princeton University Press, 2005.

This book covers the work of women computers who worked in the shadows of astronomy and math throughout history. The book included a chapter on the Harvard Observatory and led me to several excellent resources which I used for further research. Grier also discussed the women who worked at NASA during the 1950s and 60s, which led me to the book *Hidden Figures* because I was interested to find out if the women who worked at Harvard Observatory had any impact on future women computers.

Hearnshaw, John B. *The Analysis of Starlight: Two Centuries of Astronomical Spectroscopy.* New York: Cambridge University Press, 2014.

This book was a helpful resource because it provided information about the women computers and their discoveries from the perspective of astronomy and spectroscopy. In the chapter about spectroscopy at Harvard, Williamina Fleming, Antonia Maury, and Annie Cannon's work and discoveries are covered in detail. The fact that they were included in this book shows how many barriers these women broke as they worked at the forefront of a new age of astronomy in the early 19th century.

Hirshfeld, Alan. *Starlight Detectives: How Astronomers, Inventors, and Eccentrics Discovered the Modern Universe.* New York: Bellevue Literary Press, 2014.

This book tracks the shift that took place during the 19th and 20th centuries from classical astronomy to astrophysics – which initially meant the application of photography and spectroscopy to celestial objects. The development of photography and spectroscopy in the 19th century revolutionized astronomy and paved the way for institutions such as the Harvard Observatory to make ground-breaking discoveries relating the stellar spectra.

Hoffleit, Dorrit. *Women in the History of Variable Star Astronomy*. Cambridge, MA: American Association of Variable Star Observers, 1993.

This book focuses on the history of women in variable star astronomy, yet it deals primarily with the women computers at Harvard Observatory, who were at the forefront of variable star discoveries. In fact, the statistics included in this book were so surprising and incredible that I decided to include them in my performance. Of the 14,700 variable stars that had been found by 1956, 68% had been discovered by the women at Harvard Observatory. This demonstrates just how important and how expansive the women's discoveries were.

Johnson, George. *Miss Leavitt's Stars: The Untold Story of the Woman Who Discovered How to Measure the Universe*. New York: W.W. Norton & Company, 2005.

There is only one biography of Henrietta Leavitt published. When I began researching Miss Leavitt, I quickly realized that there are not many primary or secondary sources by or about her – due to her extremely private life. This book neatly summarizes most of the information that is available about Henrietta Leavitt, and gave me an idea of how to explain the slightly complex concept of Leavitt's Law in my performance.

Jones, Bessie Zaban, and Lyle Gifford Boyd. *The Harvard College Observatory: The First Four Directorships, 1839 - 1919*. Cambridge, MA: The Belknap Press of Harvard University Press, 1971.

This excellent book provided information on the history of Harvard Observatory - I found particularly useful the chapters on Edward Pickering, as well as the women computers who worked at the Observatory. Those chapters provided valuable information on the responsibilities, discoveries, and salaries of Annie Jump Cannon, Henrietta Leavitt, Mrs. Fleming, and other women computers. It also included many excerpts from primary source letters, which I was unable to access any other way.

Joskow, Melissa. "From "Computer" to Astronomer: The Role of Women in Astronomy." Smithsonian National Air and Space Museum. https://airandspace.si.edu/stories/editorial/computer-astronomer-role-women-astronomy?linkId=29133361 (accessed October 22, 2019).

This website summarized the lasting achievements of Annie Jump Cannon, Henrietta Leavitt, Cecilia Payne-Gaposchkin, and Phoebe Waterman (another woman computer who worked at a different observatory). This was an early resource I used to acquaint myself with the topic, and it led me to several other resources that proved to be very helpful.

Kohlstedt, Sally Gregory. "Sustaining Gains: Reflections on Women in Science and Technology in 20th-Century United States." *NWSA Journal* 16, no. 1 (2004): 1-26. www.jstor.org/stable/4317032. (accessed April 7, 2020).

This article covered the history of women in the 20th century who struggled to receive equal rights and recognition for their achievements. The author pointed out how while women began to go into careers in science in the 20th century, such as the Harvard computers, they rarely received equal pay, and the standards for women were so much higher than those for men. In addition, the author emphasized the importance of awards established for women, specifically, the Annie Jump Cannon Award for women in astronomy. I used this resource to strengthen my understanding of the experiences of women in science, particularly women in astronomy.

Mack, Pamela Etter. "Women in Astronomy in the United States 1875 - 1920." Bachelor of Arts, Harvard University, 1977.

This thesis was a very helpful resource, because it discussed the Harvard Observatory and the situation of women in the field of astronomy. Specifically, this stated that Harvard was the first observatory to hire women to work as computers, and they hired the largest number of women, which is evidence for "breaking barriers." In addition, this included statistics of women in astronomy (a very low percentage), as well as how many women astronomers had received higher education. This also included brief biographies of Williamina Fleming, Annie Jump Cannon, and Henrietta Leavitt.

Mariani, Gael. "Henrietta Leavitt - Celebrating the Forgotten Astronomer." American Association of Variable Star Observers. https://www.aavso.org/henrietta-leavitt-%E2%80%93-celebrating-forgotten-astronomer (accessed November 13, 2019).
This website is an excellent overview of Henrietta Leavitt's life and discoveries, and provided a basis for my knowledge of Leavitt for the performance. This also led me to the key short biography of Leavitt by George Johnson, which was an important resource for me, since it is the only biography of Miss Leavitt available.

McGrath, Alex. "Drive and Joy: Annie Jump Cannon at HCO." *Galactic Gazette*. http://www.altbibl.io/gazette/ajc.html (accessed November 16, 2019).
This blog article by a staff member of the Harvard Archives focused on Annie Cannon's life and work at the Harvard Observatory, and helped provide a better understanding of the barriers Cannon broke, as well as how to portray her in my performance. This also provided a long list of resources, which provided a jumping off point for more research.

McGrath, Alex. "Computers at Work: Astronomical labor at the HCO at the turn of the century." *Galactic Gazette*. http://www.altbibl.io/gazette/computersatwork.html (accessed November 16, 2019).
This blog entry was an excellent resource that answered several specific questions I had concerning the women at Harvard Observatory, including how much they were paid and information about the women's difficulties of working in a traditionally masculine workplace. This article really helped me develop the breaking barriers in feminism angle for my performance.

NASA. "About: Webb Space Telescope." https://jwst.nasa.gov/content/about/index.html (accessed February 19, 2020).

This website provided information about the James Webb Space Telescope, which will launch in 2021. I included this in my performance to illustrate the continuing legacy of Harvard Observatory, because the Webb Telescope will look farther than ever before into the Universe to take images that photographers and astronomers in the early 20th century could never have imagined.

Ogilvie, Marilyn Bailey. *Women in Science: Antiquity through the Nineteenth Century.* Cambridge, MA: Massachusetts Institute of Technology, 1986.

This dictionary included concise and detailed biographies of women in science throughout history, including notable astronomers such as Annie Jump Cannon, Henrietta Leavitt, Antonia Maury, Anna Palmer Draper, and Maria Mitchell. In addition, Ogilvie included an annotated bibliography for every woman in the dictionary, so I was able to find additional resources about some of the women.

Rossiter, Margaret W. "”Women's Work" in Science, 1880 - 1910." *Isis* 71, no. 3 (1980): 381 - 98. www.jstor.org/stable/230118 (accessed January 12, 2020).

This journal article from JSTOR was a great resource that discussed women in science around the beginning of the 20th century. This contained excellent insights about the women who worked at Harvard Observatory and how they impacted the creation of other similar teams of women computers around the country. This article also stated that while Pickering's vision in hiring women for computing work was a step forward for women in science, often computing was considered "women's work" and there was little opportunity for advancement within the field for women.

Smith-Zrull, Lindsay, telephone interview by Lilianna Hug. November 7, 2019.

Lindsay Smith-Zrull is the curator for the Astronomical Plates Collection at Harvard Observatory, which holds more than 500,000 glass plates. Ms. Zrull provided me with very helpful information about the Harvard Observatory, including discussions about other women working at Harvard in other departments at the same time, what contemporaries thought of the women computers, and whether the women the first team of women working at an Observatory. Ms. Zrull also sent a digital file folder with images of the women computers, glass plates, newspaper clippings, and more, which was immensely helpful in my research.

Sobel, Dava. *The Glass Universe: How the Ladies of the Harvard Observatory Took the Measure of the Stars.* New York: Viking, 2016.

This was the first book I read about the women at Harvard Observatory, and it inspired my interest in the topic. Sobel presented the stories of many of the individual women computers and their accomplishments, as well as a wonderful overview of events that were taking place in astronomy between 1882 and the late 1950's. I also really appreciated how Sobel was able to write about the history and science of this topic in an approachable way, which made the more technical aspects of astronomy understandable. In addition, the bibliography for this book was very extensive and provided many additional resources.

"Planetarium Shows: In the Charles Hayden Planetarium." Museum of Science. https://www.mos.org/planetarium (accessed February 14, 2020).

I found the website of the Charles Hayden Planetarium in the Boston Museum of Science. This was helpful as I created my set, specifically the sign for the Charles Hayden Planetarium; I used this page to find information to include on the sign for my performance.

"The Telescope." *Breakthrough: The Ideas that Changed the World*: PBS, 2019.

This PBS broadcast covered the major breakthroughs in astronomy - from the discovery in the 9th century that light travels in straight lines, to modern astronomers examining images of galaxies taken by the Hubble Space Telescope. This included a segment about the Harvard Observatory and Henrietta Leavitt and helped put my topic into greater context in the history of astronomy. This helped me realize how important photography became as it transformed astronomy in the late 19th and early 20th centuries.

Outram, Dorinda, and Pnina Abir-Am, eds. *Uneasy Careers and Intimate Lives: Women in Science, 1789 - 1979*. New Brunswick: Rutgers University Press, 1987.

This book is a collection of essays written about the lives of women in science. I found the sections on Maria Mitchell and Cecilia Payne-Gaposchkin particularly helpful because the chapters gave me an idea of the barriers faced by women in science - specifically astronomy - in the early 20th century as they tried to find balance between their careers and what was expected of them in their personal lives. These women challenged the prevalent idea of the time period that domesticity was a "woman's sphere" and there was no room for women in a career or scientific endeavors.

"Spectroscopy: Unlocking the Secret in Starlight." Australia Telescope National Facility. https://www.atnf.csiro.au/outreach//education/senior/astrophysics/spectroscopytop.html (accessed January 9, 2019).

This website contained a series of pages on spectroscopy. The "Historical Introduction to Spectroscopy", "Astronomical Spectra" and "Spectral Classes of Stars" webpages were particularly useful in my research and gave me a better understanding of the rather complex workings of spectroscopy, specifically, the different kinds of spectra, what the spectra really are, and how astronomers were able to take images of them during the late 19th and early 20th centuries when photography was a rather new technology.