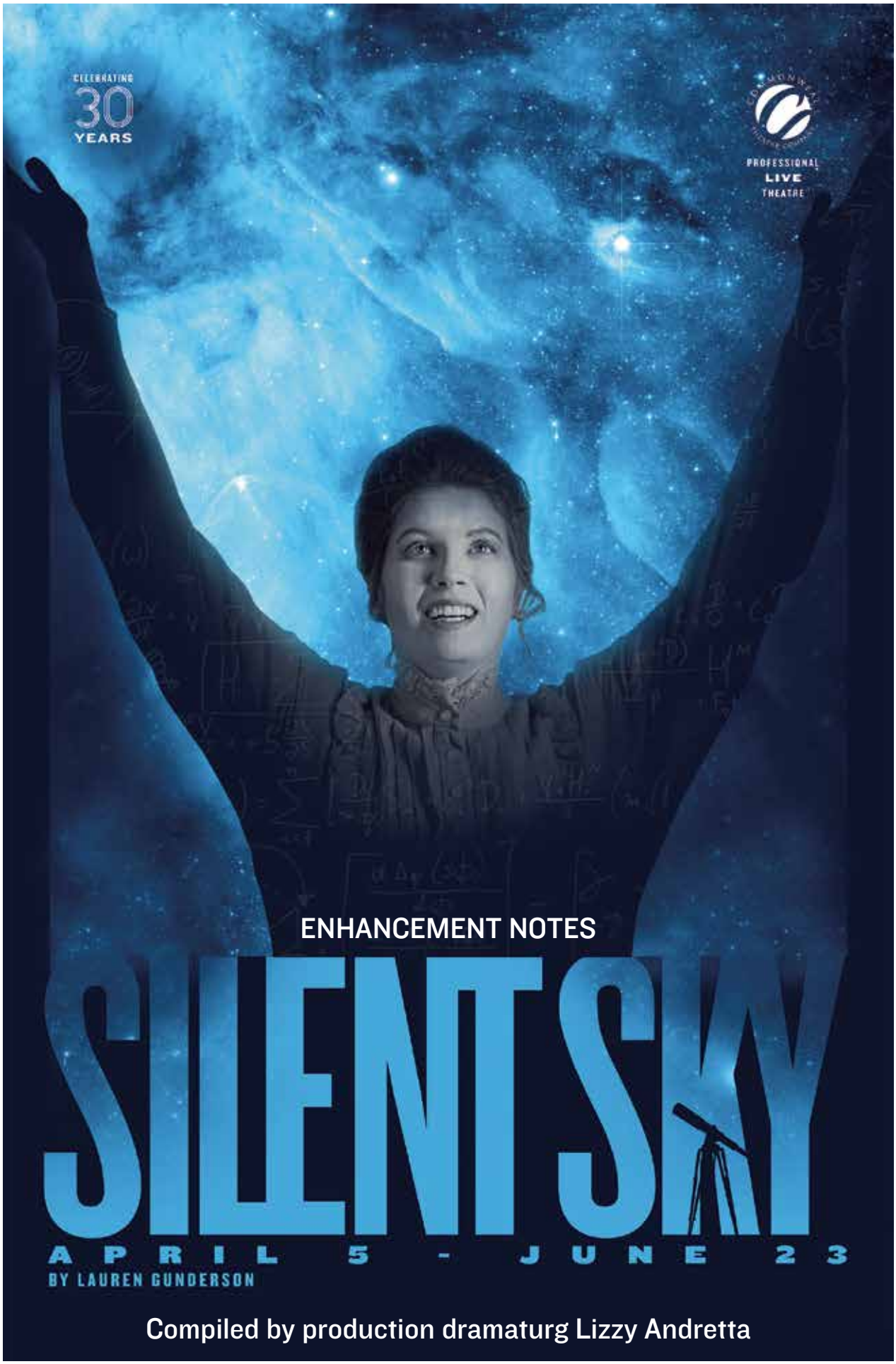


Compiled by production dramaturg Lizzy Andretta

Silent SKY

by Lauren Gunderson

Presented by the
Commonweal Theatre Company
April 5 – June 23, 2018

ESSENTIALS

The Plot

We meet Henrietta Leavitt in a fit setting—under the stars at night, at her family home in rural Wisconsin. She tells us of her faith in the stars' trustworthy light in the great dark void of space—they are her "billions of exceptions."

Now it is morning and Henri's sister, Margaret, arrives to scold her for being late to church service where their father is the minister. Henri reveals that she has been offered a job at Harvard Observatory which she plans to accept—it's the chance she's been longing for. She asks Margie to ask father for Henri's dowry, as she doesn't plan to marry and will need the money to settle in Cambridge. Margaret reveals that her suitor, Samuel, has asked Margaret to marry him. She plans to accept. The sisters reluctantly accept one another's life choices and part.

Henri arrives at Harvard and meets Peter Shaw, assistant to the department head, Dr. Pickering. He begins to show her around when the women arrive: Annie Cannon and Williamina Fleming. Henri soon learns that here, too, the women's place is entirely subservient to the men's; the men are astronomers, the women merely "computers."

The Harvard Observatory c. 1890.

Discouraged, Henri begins to settle into the work. Peter comes around often, delivering new star plates for the women to analyze and betraying a growing interest in Henri. Her work centers on Cepheid variable stars. She finds more than anyone else and senses that there is something important in their study waiting to be discovered. Though Henri is frustrated by a lack of apparent progress, Annie encourages her to continue.

Meanwhile, Henri and Peter are falling in love. He invites her along on a transatlantic voyage to see the stars from shipboard and an eclipse in Europe and to meet other astronomers. She reluctantly declines, determined to keep working. They take their leave of each other, promising to be "afar but not apart."

Henri's father suffers a stroke and she must rush home to Wisconsin to help her sister manage the household. She asks the Observatory to send star plates to her at home so she can keep working, and they do. She has become vital to other astronomers, who call her a "star-finding fiend."

Her absence from Harvard stretches into years, during which Peter has stopped writing. Eventually, her father passes and her sister urges her to return to Harvard. Before Henri leaves home, her sister's music triggers an inspiration that leads Henri to her great discovery: the Cepheid variables' periodicity is related to their luminosity. As the act closes, she realizes that she has arrived at a "standard candle" for measuring the universe!

Act II opens with Henri fantasizing a sea voyage with Peter, but the reverie is broken as Peter himself arrives. His standoffish behavior confuses Henri. Williamina bustles in with a copy of Henri's published findings to congratulate her. To Henri's shock, Peter reveals that he has married. Rather than suffer ungracefully, Henri decides to take a transatlantic trip of her own.

On her return to Boston, Henri is greeted by her sister and Williamina and Annie. We learn that Henri is gravely ill but still eager to work. Margaret joins her in Cambridge to care for her. Henri is eager to learn the latest astronomy news but feels shut out by the men who seem to ignore her.

Peter visits to share the news that her discovery has been used by other astronomers to calculate the size of the universe. Her work is vindicated and he says he is proud to know her. The ladies are also present and, to celebrate, they whisk her off to Harvard's Great Refractor telescope, which had been off-limits to the women all the years they worked under its shadow.

Finally seeing the universe the way she always dreamed it to be, Henrietta tells us the story of her own future, and that of her friends, and that of the science of astronomy she has so steadfastly loved.

Silent Sky

by Lauren Gunderson

Director	Adrienne Sweeney
Stage Manager & Assistant Director	Philip Muehe
Assistant Stage Manager	Amanda Pyfferoen
Production Stage Manager	Bailey Otto
Costume Designer	Janis Martin
Scenic Designer	Kit Mayer
Lighting Designer	Paul Epton
Sound Designer	Matt Vichlach
Assistant to the Sound Designer	Kelsey Heathcote
Props Designer	Brandt Roberts
Graphic Designer	Ben Gorman
Dramaturg	Lizzy Andretta

Cast

Henrietta Leavitt	Megan K. Pence
Margaret, her sister	Abbie Cathcart
Peter Shaw	Eric Lee
Annie Jump Cannon	Elizabeth Dunn
Williamina Fleming	Stela Burdt

Setting

The Leavitt family home in rural Wisconsin; Cambridge, Massachusetts; on shipboard in the Atlantic. 1900 - 1920.

SILENT SKY is presented by special arrangement with Dramatists Play Service, Inc.

About the Playwright

Lauren Gunderson is a playwright and author from Atlanta, Georgia. She received her B.A. in English/Creative Writing from Emory University and her M.F.A. in Dramatic Writing from NYU Tisch. She was named the most produced playwright in America in 2017 by *American Theatre Magazine* and has won such awards as the 2016 Lanford Wilson Award from the Dramatist Guild, the 2016 Otis Gurnsey Award for Emerging Writer and the 2014 Steinberg/ATCA New Play Award (for her play *I and You*). She also received the Mellon Foundation's 3-Year Residency with the Marin Theatre Company. Some of her works include *Miss Bennet: Christmas at Pemberley* (with Margot Melcon) and *Exit, Pursued By A Bear*, among others.

Silent Sky was commissioned by and premiered at South Coast Repertory in Costa Mesa, California as part of the 2011 Pacific Playwrights Festival. When asked about the message she believes the play holds for audiences, Gunderson replied, "…that women aren't asking for special treatment, we are showing how special we already are and always have been. We're not asking anyone to let us participate, we are exclaiming that we have participated in discoveries, breakthroughs and wild achievement all along (despite being excluded, barred and presumed incapable)." (Austin Playhouse)

Context – Historical Setting

World War I

Lasting from 1914 to 1918, World War I was a conflict sparked by the assassination of Archduke Franz Ferdinand. Noteworthy for its use of new military technology and for the horrific employment of trench warfare, a monumental level of carnage and destruction marked "The Great War." The end of the war saw the Allied Powers (Great Britain, France, Russia, Italy, Romania, Japan and the United States) claim victory over the Central Powers (Germany, Austria-Hungary, Bulgaria and the Ottoman Empire), at the cost of more than 16 million lives.

While the United States initially adopted President Woodrow Wilson's policy of neutrality in response to the war, Germany's submarine aggression against neutral ships was making that policy extraordinarily difficult. In May 1915, a German U-boat sank the British Ocean liner Lusitania as it was travelling from New York to Liverpool with hundreds of American passengers onboard. The widespread outcry against this act led to a shift in American public opinion against Germany. When Germany sank four more U.S. merchant ships, Woodrow Wilson appeared before Congress on April 2nd and declared war against Germany.

After several battles, including the Second Battle of the Marne on July 15, 1918 that would mark the last German offensive of the war, the tide began to turn in favor of the Allies. The year 1918 saw the Turks sign a treaty in late October, Austria-Hungary dissolving from within and reaching an armistice on November 4th, and Germany being forced to seek an armistice on November 11th, finally ending the war.

Trench warfare characterized World War I.

Referred to as "the first modern war," World War I had lasting consequences for all those involved, including but not limited to the spread of the deadly flu epidemic of 1918 that killed around 20 to 50 million people, use of tanks, machine guns and aerial combat, and millions of women entering the workforce both to support men who went to war and to replace those who would never return.

Feminism in America

"If we can organize the sky, we can organize our minds to choose our own future."

—Annie, *Silent Sky* (p. 56)

If you were to ask most historians, they would tell you that feminism in America could be divided into waves, each representing a different period in history. *Silent Sky* takes place during what we would call the "first wave" of feminism in the late nineteenth and early twentieth centuries. To help put the first wave into perspective, it is important to note that at the time the movement was beginning to take root, women across America were legally forbidden from voting, owning property, attending university, gaining legal custody of their children, or refusing to have sex with or divorcing their husbands. Thus the main focus of the first wave became the acquisition of equal rights for women and to end the oppression women faced both in the public arena and in the privacy of her home. Some landmark events that occurred during the first wave include the Seneca Falls Convention in 1848 (the first women's rights convention),

☞

the Ohio Women's Convention in 1851 where Sojourner Truth delivered her now famous "Ain't I a Woman?" speech, the March for Women's Suffrage in Washington in 1913, Margaret Sanger opening the first birth control clinic in the United States in 1916, and the passing of the 19th Amendment in 1920, to name a few.

The Suffrage Movement

"We need a vote, girls. It's about equality—and it's about time!"

—Annie, *Silent Sky* (p. 56)

Most suffragists marked the official beginning of the suffrage movement as a women's rights convention held in Seneca Falls, New York, in 1848. Over the ensuing 50 years, suffragists made it their mission to convince the public that the cause of women's suffrage was a valid one worth fighting for. When the turn of the century came around, women's rights pioneers wanted to pass reform legislation, but hit a roadblock when most politicians were unwilling to support a disenfranchised group. Thus the main goal of the movement became to persuade Congress to pass a constitutional amendment that would give women the right to vote.

1913 saw a divide happen in the movement. After a parade organized by the National American Woman Suffrage Association (NAWSA) broke out in riots, suffragist Alice Paul wanted to follow the British example and organize more protests and demonstrations to help secure the vote. However NAWSA opposed any tactic that might result in violence and preferred more traditional methods like lobbying and petitions. Paul and a number of more militant suffragists soon broke away from NAWSA and founded the National Women's Party. Their use of more militant tactics most likely resulted in the image of suffragists as radical and dangerous ("whiskey with suffragettes").

Things came to a head on March 3, 1913, when more than 5,000 women traveled to Washington, on the eve of Woodrow Wilson's inauguration, to fight for the vote (it was the original Women's March). Although the participants were harassed and heckled, the march was a turning point for the Suffrage movement, and six years later Congress passed the 19th Amendment, enfranchising women nationwide.

Farm Life in Rural American (early 1900s)

Henrietta: Where are we?!
Margaret: Wisconsin.
Henrietta: In the universe!
Margaret: Still Wisconsin.

—*Silent Sky* (p. 12)

At the beginning of the twentieth century, almost half the population of the United States of America lived on farms. Despite the invention of new technologies at this time, most of the work on a farm was done by hand and with the assistance of animals such as horses and oxen. Because there was no electricity, at night work had to be done either by candlelight or in the dark. Despite, or perhaps because of, the harshness that accompanied such a life, most farmers and their wives possessed a self-sufficiency that is rarely seen today. Indeed, the typical lack of help on a

☞

farm meant the so-called "farm wives" were often required to learn and do most of the labor-heavy jobs required of their husbands, in addition to doing what was considered more "feminine" work (e.g., laundry, cooking, raising the children). Tasks and chores that a woman might be expected to assist with included plowing, sowing, gardening and harvesting, to name a few. Because there were so many tasks and not enough people to accomplish everything that needed doing in one day, a farmer never had what one might describe as a "typical day's work." Days typically started early, with one account written by an anonymous farm wife in 1900 stating that she was often up at four o'clock in the morning. Most farm-raised girls and women were educated and attended school until they were married, at which point they were expected to focus solely on the needs of their husbands and households or risk the wrath of their husbands.

Settings / Places

The Harvard Observatory and Pickering's Harem

"Harvard Observatory is the pinnacle of the astronomical community. The academic world looks to us."

—Annie, *Silent Sky* (p. 17)

The Harvard Corporation, with William Cranch Bond serving as the first "astronomical observer," established the Harvard Observatory in 1839. A few years later, a "great comet" sailed across the sky, which prompted the need for a telescope, after which the Great Refractor was installed in 1847 (complete with a lens imported from Munich). Photographs of the moon taken by Bond and John Adams Whipple earned a prize at the Great Exhibition of 1851 in London, bringing more esteem to the Observatory.

In the 1890s Edward Charles Pickering took over as director of the Observatory. He placed more of an emphasis on research, with the staff undertaking projects to study and photograph both the northern and southern celestial hemispheres. He was faced with a dilemma in 1881 when his staff was proving unable to analyze the large amount of data coming their way. Frustrated, he eventually fired his male assistant and replaced him with his Scottish housekeeper, Williamina Fleming. After she proved herself to be exceptional at copying and computing, Pickering eventually hired more women, with more than 80 working at the Observatory from 1877 to 1919. Working mostly on computing and cataloguing data, the women came to be known as "Pickering's Harem." "Harem-ing," or hiring women to do traditional men's work, became popular at the time in many fields, as women were considered better at doing detail-oriented work than men, but they were cheaper to employ.

Another term used to describe the women was "computers." Unlike what we know today, in the early 1900s a "computer" was a term used to describe a person who did calculations manually. The women's job at the Observatory consisted of looking at photographic plates of the night sky, establishing stars' brightness and recording it along with their positions. Because women were considered at the time to be too weak to do scientific work, they were mostly limited to doing what would be considered volunteer work. The computers were typically paid 25 to 30 cents an hour and worked six days a week.

Radcliffe College

"Mr. Shaw, I also graduated summa cum laude, from Radcliffe, which is basically Harvard in skirts."

—Henrietta, *Silent Sky* (p. 15)

Elizabeth Cary Agassiz and a group of men and women associated with Harvard who wanted to create an institution for the education of women founded Radcliffe College in 1879 in Cambridge, Massachusetts. When first established, the school was dubbed the Society for the Collegiate Instruction of Women (or the "Harvard Annex," denoting the school's connection to the esteemed institution). The main purpose of the College was, as stated by its founders, "to furnish instruction and the opportunities of collegiate life to women and to promote their higher education." In 1894, the school was chartered and renamed Radcliffe College by the Commonwealth of Massachusetts. In 1999, Radcliffe College and Harvard officially merged, creating the Radcliffe Institute for Advanced Study at Harvard.

The Women

Henrietta Leavitt

"Miss Leavitt was of an especially quiet and retiring nature, and absorbed in her work to an unusual degree. She had the highest esteem of all her associates at the Harvard Observatory, where her loss is keenly felt."

—Solon I. Bailey, "Henrietta Swan Leavitt" (*Popular Astronomy*)

Henrietta Swan Leavitt was born in Lancaster, Massachusetts on July 4, 1868. Her parents were George Roswell Leavitt, a congregational minister, and Henrietta Swan Kendrick and she was the eldest of seven children, two of who died in infancy. The Leavitt family was able to trace its ancestry back to Deacon John Leavitt (or Levett, as it was spelled in the early Massachusetts records), an English Puritan tailor who settled in the Massachusetts Bay Colony in the early seventeenth century.

As an adult, she attended Oberlin College for two years where she studied music, then transferred to Radcliffe College, then called the Society for the Collegiate Instruction of Women, where she earned her bachelor's degree in 1892. Throughout her time at school, she studied topics such as calculus, classical Greek, fine arts, philosophy and analytic geometry, however she didn't take her first course in astronomy until her fourth year. After her graduation, she obtained credits towards a graduate degree for astronomy, but she never completed the degree. Her interest in astronomy led her to seek work as a volunteer assistant under Pickering at the Harvard Observatory in 1895. Because she was technically a volunteer and had her own means of income, Pickering didn't pay her when she started working at the Observatory. Later, he ended up paying her 30 cents an hour ($10.50 per week). Like many of the other members of "Pickering's Harem," Leavitt's initial tasks involved measuring and cataloguing the brightness of the stars based on their appearance in the photographic plates (women not being allowed to use the famous Great Refractor Telescope at the time). Despite being surrounded by all this great technology, Leavitt was not allowed to pursue her own scientific

☞

interests, but was beholden to whatever Pickering wanted her to observe.

From 1896 to 1897, Leavitt traveled throughout Europe, and then to Beloit, Wisconsin (where her father served as a pastor) upon returning to America. Sometime during her travels, Leavitt suffered from a serious illness that cost her her hearing (she also had issues with her eyesight, but it got better).

She eventually returned to the Observatory in 1902, whereupon Pickering offered her a permanent staff position with pay (the aforementioned 30 cents an hour). She was soon put to work on what Pickering called the Observatory's "Great Project" that involved determining the brightness of all measurable stars. Her specific assignment was to study "variable stars," those with luminosity that varies over time. As she studied the Cepheid variable stars in the images of the Magellanic Clouds, Leavitt noted that some of the brighter variables' period of fluctuation is related to their brightness. Further study confirmed this discovery, which came to be known as the "period-luminosity relationship" or "Leavitt's Law."

Leavitt also developed and refined Harvard's standard for photographic measurements. Because there was no set system for determining magnitudes at the time, Leavitt came up with her own system by using the "north polar sequence" to help gauge brightness for stars during her studies. The system gained recognition by the astronomical community and was adopted by the International Committee on Photographic Magnitudes.

Leavitt's contributions were so great that she was named Head of Stellar Photometry of the Observatory in 1921. Unfortunately her ill health and a swarm of family obligations meant that her work was often sidelined. She died of cancer on December 12, 1921, and was buried in the Leavitt family plot in Cambridge.

In 1926, Magnus Gosta Mittag-Leffler, member of the Swedish Academy of Arts and Sciences, attempted to nominate Leavitt for a Nobel Prize in physics for her work. However, he did not realize at the time that she had passed away, and Nobel Prizes are not awarded posthumously.

Annie Jump Cannon

"In our troubled days it is good to have something outside our planet, something fine and distant for comfort."

—Annie Jump Cannon

Annie Jump Cannon was born on December 11, 1863, in Dover, Delaware, to Wilson Cannon, a shipbuilder and state senator, and Mary Jump, his second wife. Her mother was a key figure in her interest in astronomy, as she would often take Annie up to the attic to observe the constellations. When she was older she attended Wellesley College, where she chose to major in physics because astronomy was not yet available at the five-year-old institution.

Following her graduation in 1884, she returned home and contracted scarlet fever, which resulted in her hearing being permanently damaged. She eventually became a "special student" of astronomy at Radcliffe College following the death of her mother in 1894, which helped give her access to the Harvard Observatory. Following the end of

her course in 1896, Cannon began working at the Harvard Observatory under Edward Pickering with the intent of cataloguing and classifying the stars. Cannon's initial job at the Observatory, like all the other female computers, involved simple computing and classification.

☞

As she kept classifying and studying more and more stars, she realized that she needed to develop a new classification system. Using Williamina Fleming's classification system as a basis, Cannon developed a system of grouping the stars based on temperature, ranging from hottest to coolest, with the letter designations O, B, A, F, G, K, M. The system was not only adopted as a standard for astronomers, but was also given the mnemonic device "Oh, Be A Fine Girl, Kiss Me" which is still used today. From 1901 to 1907, Cannon published her findings on the variable stars in the *Annals of the Astronomical Observatory of Harvard College* in three separate volumes.

As she kept working, she became involved in the women's suffrage movement and joined the National Women's Party (known for their more radical approach to suffrage). In 1929, the National League of Women Voters listed her as one of the twelve greatest living American women.

Over the course of her career she classified more than 350,000 stars and discovered 300 variable stars, five novae and one binary star. Even as she grew older she continued to work seven days a week until she died from heart disease at the age of 76 on April 13, 1941, in Cambridge, Massachusetts.

Williamina Paton Fleming

"While we cannot maintain that in everything woman is man's equal, yet in many things her patience, perseverance and method make her his superior."

—Williamina Paton Fleming

Williamina Stevens was born in Dundee, Scotland on May 15, 1857, to Mary Walker Stevens and Robert Stevens. As the daughter of a local craftsman, Williamina (or "Mina," as she was called by friends and family) was a constant fixture in the public schools. Her intelligence and talent for school became more obvious as she grew, and she began student teaching at the young age of fourteen. Her career as a teacher lasted until 1877, when she married James Fleming. A little over a year later the Flemings sailed to America, eventually settling in Boston where Fleming's brothers had previously settled. A few months after arriving, James abandoned his wife and unborn child for reasons unknown to history.

Left alone in a foreign country with no means to support herself and her child, Fleming accepted a job as a housekeeper to Edward Pickering, director of the Harvard College Observatory. Pickering's wife recognized Fleming's abilities and Pickering gave her a part-time job as a copyist and computer. One rather famous account of her hiring states that Pickering began to grow dissatisfied with the work of his male employees at the Observatory, whereupon he stated that his maid could do a better job than they did. Fleming soon proved herself more than capable, and her work ethic and intelligence led to her being given more responsibilities, including interviewing prospective applicants to the Observatory and supervising the female workers. One noteworthy woman supervised by Fleming was Henrietta Leavitt, whose work allowed scientists to measure the universe.

A major step in her career came when astronomer Henry Draper's widow, Anna, gave the Observatory funding in 1886 to help with her husband's project to catalogue the entire night sky. While Nettie Farrar was initially assigned the task of cataloging and examining the photographic plates required for the project, she eventually left the Observatory in order to get married, leaving Fleming to take her place. Fleming developed a new system of classifying stars according to their spectra, or "the unique pattern of lines caused by the refraction of a star's light through a prism." This system was created out of dissatisfac-

☞

tion with a previous system. The new system, eventually dubbed the "Pickering-Fleming System," helped Fleming catalogue over 10,000 stars over the next nine years. Her discoveries were published in 1890 in the Draper Catalogue of Stellar Spectra. Although Pickering was given most of the credit for the work (though he did acknowledge her in the introduction), Fleming's contribution received a great deal of attention and made her well known within the astronomical community.

After the publication of the Draper catalogue, Harvard granted her the title of "Curator of Astronomical Photographs" in 1898, the first woman to hold such a title. She was further honored in 1906 when the Royal Astronomical Society elected her as a member, again marking a milestone as the first American woman to join. Throughout her career, Fleming made numerous discoveries including but not limited to 10 novae, 52 nebulae, 310 variable stars, and most importantly, white dwarfs. She died of pneumonia on May 21, 1911 in Boston at the age of 54.

The Science

Astronomy

"Heaven's up there, they say. 'Pearly clouds, pearly gates,' they say. They don't know much about astronomy, I say."

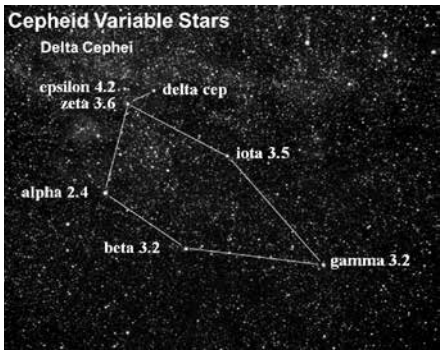
—Henrietta, *Silent Sky* (p. 9)

Defined as "(studying) the sky and learning about what we see in the universe," astronomy is one of humanity's oldest sciences (Greene). Astronomy is one of the rare sciences that can be practiced casually (stargazing from one's backyard) or professionally (being trained to do in-depth studies of the stars in a scientific environment).

While people in ancient times relied solely on their eyes and observation skills to chart the skies and passage of time, the invention of technology such as the telescope has allowed a more detailed look at what lies beyond our planet. Such technological advancements have also allowed for the application of science and mathematics to the practice of astronomy, which in turn has helped astronomers make even greater discoveries. The main focus of most astronomy studies is the stars (including the sun), of which there are around a trillion in the Milky Way Galaxy, which is itself one of many galaxies in the universe. The actual science of astronomy can be broken down into several sub-categories: planetary science (the study of planets, moons, rings, asteroids and comets), solar physics (study of the sun and its effects on the solar system), astrophysics (study of the stars and galaxies), radio astronomy (using radio telescopes to study radio frequencies present in the universe), astrometry (measuring distances in the spaces between objects), mathematical astronomy (use of numbers and calculations to study space) and cosmology (the study of the universe as a whole).

Cepheid Variable Stars

Cepheid Variable Stars are pulsating stars that have been used to measure distances and ages of astronomical objects. They are very luminous, more so than the sun, and exhibit short-period changes of brightness (luminosity) that range from 1 to 100 days. Astronomers have measured the distances to Cepheids using their luminosity, making them responsible for some of the greatest discoveries in science.



The Magellanic Clouds

The Magellanic Clouds comprise two irregular galaxies known as the Large Magellanic Cloud (LMC) and the Small Magellanic Cloud (SMC). They are visible to the naked eye from Earth's southern hemisphere and near-equator locations. They were named for 15th century Portuguese explorer Ferdinand Magellan, who used them for naval navigation.

Both these galaxies are gravitationally entangled with the Milky Way Galaxy and with each other. Only 150,000-200,000 light years away from the Milky Way, the Magellanic Clouds were thought to be the closest galaxies until the recent discovery of the Sagittarius and Canis Major dwarf galaxies. Henrietta Leavitt was studying variable stars in the SMC when she discovered the period-luminosity relation for Cepheids, thus helping broaden our understanding of the universe.

The Small and Large Magellanic Clouds.

Newton v. Einstein

Williamina: Physics was about wrapped up!
Peter: Yes.
Williamina: But then that fuzzy-headed man blew up your stately foundation.
Peter: You're not supposed to do that to Isaac Newton.

—*Silent Sky* (p. 29)

In 1687, Isaac Newton proposed the existence of gravity, a force he could not explain but which he precisely defined mathematically. He described gravity as "an ever-present force, a tug that all objects exert on nearby objects. The more mass an object has, the stronger its tug. Increasing the distance between two objects weakens the attraction." When curious minds questioned how this force was supposed to work, Newton was unsure. When pressed, he simply stated "Gravity must be caused by an agent acting constantly according to certain laws."

For hundreds of years after this discovery, Newton's "laws of motion" and his principles of gravitation remained unchallenged, taking on the monolithic name Newtonian mechanics. That changed in 1915, when Albert Einstein posited his theory of General Relativity. While Newton believed gravity to be an omniscient force, Einstein believed that it was actually the result of a mass's presence in the space around it, something that Newton himself didn't believe. Einstein successfully discredited Newton's theory on this main point:

"If, as Newton claimed, gravity was a constant, instantaneous force, the information about a sudden change of mass would have to be somehow communicated across the entire universe at once. This made little sense to Einstein. By his reasoning, if the sun disappeared suddenly, the signal for the planets to stop orbiting would logically have to take some travel time…Nothing universally instant about that at all."

—Essay:
"Newton vs. Einstein vs. the Next Wave"

Statistical Parallax

"He used statistical parallax for the zero-point against the sun, then plugged in your data for the slope and…there you have it."

—Peter, *Silent Sky* (p. 58)

Stellar parallax is "the apparent angular displacement of a celestial body due to its being observed from the surface instead of from the center of the earth…or due to its being observed from the earth instead of from the sun." (Dictionary) To an observer, any object in the middle distance will appear to shift its position against more distant background objects when the position of the observer changes. You can easily see this phenomenon in action by holding your thumb at arm's lenght from your face, then looking at it successively through each of your eyes, one at a time. You should notice that your thumb's position against the opposite side of the room (or outdoor background) changes. Using trigonometry, astonomers can calculate the distance to nearby stars based on observations of them made from opposite sides of Earth's orbit around the sun (equivalent to your two eyes, but on a much larger scale).

Statistical parallax is the mean parallax of a collection of stars, discovered by analyzing any of their particular motions statistically.

The Period-Luminosity Relation

"A straight line can readily be drawn among each of the two series of points corresponding to maxima and minima, thus showing that there is a simple relation between the brightness of the variables and their periods."

—Henrietta Leavitt

Published in 1912 by Henrietta Leavitt, the period-luminosity relation states that, for certain Cepheid variable stars, their period of luminosity is directly related to their brightness—the brighter the star, the longer its period of variability.

Hertzsprung and The Period-Luminosity Relation

Peter: This morning, Hertzsprung—the Danish one?
Henrietta: Big beard.
Peter: Right. He used your work to measure the distance to those Cepheids.

—*Silent Sky* (p. 57)

After the publication of Leavitt's findings, Danish astronomer Ejnar Hertzsprung was one of the first to recognize the importance of the discovery. Taking the data provided by Leavitt regarding the Cepheids' brightness, Hertzsprung used his own data to determine the distance to the Cepheids in the Small Magellanic Cloud.

Edwin Hubble and the Discovery of the Cosmos

Peter: Oh. And another man keeps writing. Hudgins?
Henrietta: Hudgins. Hubble?
Peter: (*Aha!*) *Hubble*. Yes.

—*Silent Sky* (p. 58)

Edwin Hubble was born on November 20, 1889, in Marshfield, Missouri. He obtained his undergraduate degree in Mathematics and Astronomy from the University of Chicago in 1910 and was working towards his doctorate in Astronomy when he enlisted to fight in World War I in 1917. When he returned to the United States in 1919, he immediately went to work at the Mount Wilson Observatory in Pasadena, California, having been asked to join the staff by founder George Ellery Hale before the war. Mount Wilson, home of the 100-inch Hooker Telescope (the most powerful one on Earth), was the home of intense observational work centered on astrophysics (or cosmology). At the same time

☞

Hubble came to work at the Observatory, Harlow Shapely was using Henrietta Leavitt's method of measuring the stars based on light variations from the Cepheids to discover that the width of the Milky Way was roughly 10 times what was previously expected. However this discovery was hampered by the fact that Shapely shared the commonly held belief at the time that the Milky Way Galaxy was the extent of the Universe.

That changed in October 1923 when Hubble spied what he initially believed to be a nova star flaring up in the M31 "nebula" in the Andromeda constellation. After examining the photographic plates taken of the area, Hubble discovered that the flare was a Cepheid. He then used Shapley's (derived from Leavitt's) method to measure the distance of the new Cepheid, upon which he discovered that what was first believed to be a nebula within the Milky Way Galaxy was in fact an entirely separate galaxy that was two million light-years away.

After this momentous discovery, Hubble continued to work at Mount Wilson until 1942, when he went to serve in World War II. Following the war he returned to the Observatory, where he contributed to the construction of the Hale 200-inch Telescope. One of

his major goals in life was to obtain a Nobel Prize, but his efforts were in vain as there was no category for astronomy. He died on September 28, 1953, at the age of 63 from a stroke. The Hubble Space Telescope bears his name.

Star Classifications and Spectral Classes

"Oh, Be a Fine Girl, Kiss Me!"

Henrietta: You created a…standard, Miss Cannon…my professors made us memorize your letters using this ridiculous phrase—

Williamina: She also made up that ridiculous phrase.

—*Silent Sky* (p. 18)

One of Annie Jump Cannon's major contributions to astronomy was her system that classified stars according to their surface temperature, with the different temperatures being represented by the letters O, B, A, F, G, K, M (which in turn led to the coining of the mnemonic phrase seen above). These letters are referred to as spectral classes. In the system the O stars are the hottest and are noted by their blue color, and the M stars are red and the coolest. Within the sequence, the stars at the beginning are sometimes referred to as "early-types" while those at the end are called "late-types," and decimal digits are used to create subdivisions (for example B0, B1, etc.).

Stellar Classification Chart

Spectral Class	Surface Temp. (°K)	Color
O	> 25,000	Blue
B	11,000 - 25,000	Blue-white
A	7,500 - 11,000	White
F	6,000 - 7,500	White
G	5,000 - 6,000	Yellow
K	3,500 - 5,000	Orange
M	< 3,500	Red

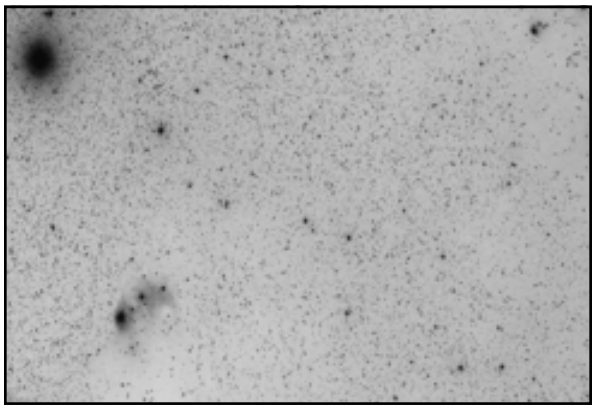
Technology

Photographic Plates

"Well. Here you go. One of the plates you'll be working with. A slice of heaven."

—Peter, *Silent Sky* (p. 16)

In the early days of astronomy, photographic plates were the main means of studying and capturing images of the stars. A photographic glass plate is essentially a rectangular piece of glass coated with photosensitive emulsion that has been exposed to starlight from a telescope. The emulsion is photochemically marked by the selection of stars observed in the night sky. On the glass plates, the stars appear as black dots, and nubulae as grey smears. The Harvard Observatory houses the largest collection of glass telescopic plates, mostly due to the fact that Edward Pickering recognized the importance



of photographing and cataloguing as much of the night sky as possible and put his staff to work collecting data. Harvard's collection contains plates made until around 1989, and is still studied by astronomers today.

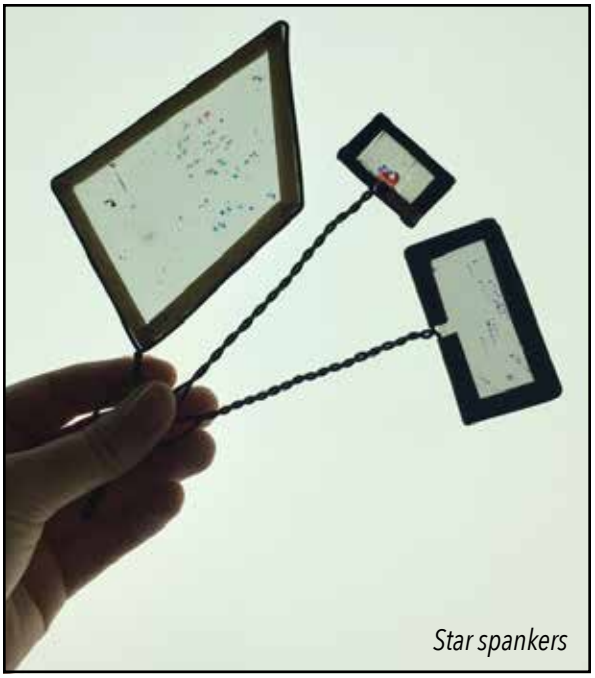
Star Spankers

Peter: I saw the light and I thought, "Well I wonder how all the spanking is going."
Henrietta: Might we all agree to another name for that?"

—*Silent Sky* (p. 33)

Developed by Henrietta Swan Leavitt, "star spankers" were created out of a need to determine the brightness of the stars shown on the plates. The spanker consisted of a piece of a photographic plate with a wire handle that could be positioned in front of a glass plate. Because star images on the plate fragment had an established brightness, Henrietta could compare the stars on the fragment to new stars she was cataloging on the plates.

She named the tool a fly spanker because it resembled a flyswatter but it was "too small to do a fly much damage."



Star spankers

The Great Refractor Telescope at the Harvard Observatory.

The Great Refractor Telescope

"On top of a hill…Just blocks away…Across the courtyard from my old desk…where it stood off-limits…I see. The Great Refractor Telescope."

—Henrietta, *Silent Sky* (p. 61)

Installed at Cambridge in 1847, for 20 years the 15-inch "Great Refractor" telescope was the largest telescope in the United States, the most significant American astronomical instrument and on par with some of the greatest instruments in the world. Constructed alongside the Harvard Observatory, the telescope was built to be a twin to a telescope constructed in 1839 for the Poulkovo Observatory in Russia. Some major observations and discoveries made by the Great Refractor include the eighth satellite and inner ring (crape) of Saturn, the first daguerreotype of a star (Vega) and one of the earliest photographs of a double star. The telescope was active for nearly three-quarters of a century, during which time it was mostly used for determining stellar positions, visually observing stars, planets, comets and nebulae, and photometry (its main use under Edward C. Pickering).

The Henry Draper Catalogue

"...the Draper Catalogue is *all* her work—She discovered stars, and nebulae, novae…I am the first to admit that she is fundamental to this institution."

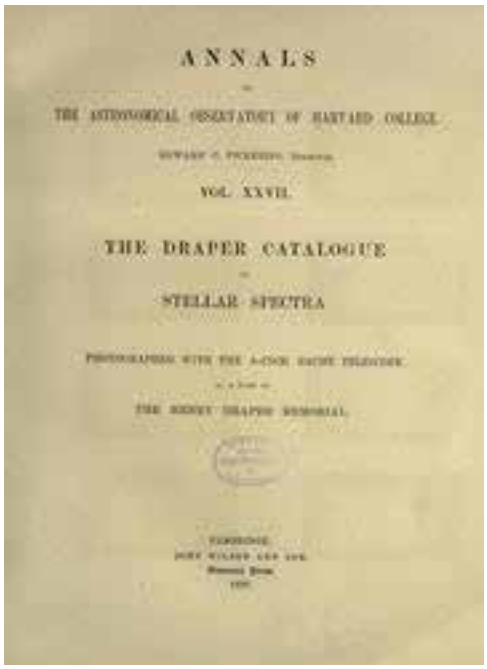
—Annie, *Silent Sky* (p. 18)

Upon the death of her husband, astronomer Henry Draper, in 1882, Anna (Palmer) Draper set about attempting to complete her husband's lifelong dream of cataloguing the stars. When she couldn't complete the task on her own, she turned to Edward Pickering and the Harvard Observatory for help in 1886. With the necessary funds and equipment donated by Mrs. Draper, Pickering undertook this cataloguing project, at the time called the Henry Draper Memorial.

Directed by Pickering, Nettie Farrar was initially the supervisor of the project, however her impending marriage caused her to depart both the project and the Observatory. In her place, Williamina Fleming took charge, and the first edition of *The Draper Catalogue of Stellar Spectra* was published in 1890, with 10,351 stars listed. As computers like Annie

☞

Jump Cannon and Antonia Maury continued to study and classify more and more stars, it became clear that the catalog would have to be updated to reflect the new discoveries. New sections were published between 1918 and 1924, with the stars numbering around 225,300. A further extension in 1949 contained 359,083 known stars.


ANNALS

VOL. XXVII.

THE DRAPER CATALOGUE

STELLAR SPECTRA

The Telephone Hearing Aid

"HENRIETTA LEAVITT…almost always wears a period hearing-aid."

—*Silent Sky* (p. 4)

The first electric hearing aid was developed at the turn of the 20th century. Based around the idea of the early telephone, these aids employed a carbon microphone that used sound waves to compress carbon against a diaphragm. Unfortunately, they proved mostly ineffective for those suffering from serious hearing loss.

Art & Culture

Bloomers

Margaret: Do not start wearing bloomers.
Henrietta: Margie.
Margaret: Wait. There are women these days, and they wear pants, and it's ridiculous.

—*Silent Sky* (p. 11)

Named for women's rights activist Amelia Jenks Bloomer, bloomers were a women's garment designed to be worn on the lower body (what we would call pants or trousers today). They were usually made of cotton and gathered at the waist and below the knees to be worn under skirts and dresses. Before they were associated with women's rights, bloomers were proposed by the Water-Cure Journal as a more healthy style of dress to corsets and restrictive dresses. As the women's rights movement took off, Amelia Bloomer and several other activists promoted the garment as a more progressive fashion statement that allowed freedom of movement. Several men and women criticized the new fashion choice as being unnatural, as many were conditioned

☞

to believe that a woman's form should be obscured by multiple layers of petticoats. As time went on, however, more and more women began to adopt bloomers as they proved to be more comfortable, warm, and practical than skirts. What helped make bloomers a common outer garment was the rise of sports, particularly bicycling, though some still considered the idea of a woman wearing a pant-like garment in public indecent.

"For the Beauty of the Earth"

We hear Margaret singing "For the Beauty of the Earth."

—*Silent Sky* (p. 13)

"For the Beauty of the Earth" was written by Folliott Sandford Pierpoint in 1865 as a hymn for the Lord's Supper. Pierpoint wanted to write a hymn that expressed gratitude toward Christ for his mercy, love and sacrifice. Editors have since changed the lyric of the refrain, making the song a more generic hymn of thanksgiving.

For the beauty of the earth,
for the glory of the skies,
for the love which from our birth
over and around us lies.

Refrain:
Christ, our Lord, to you we raise
this, our hymn of grateful praise.

For the wonder of each hour
of the day and of the night,
hill and vale and tree and flower,
sun and moon and stars of light,
[Refrain]

For the joy of human love,
brother, sister, parent, child,
friends on earth, and friends above,
for all gentle thoughts and mild,
[Refrain]

For yourself, best gift divine,
to the world so freely given,
agent of God's grand design:
peace on earth and joy in heaven.
[Refrain]

"The Observatory Pinafore"

"I sing. Gilbert and Sullivan—I wanted to be an actor—Dad thought not—But—I still sing—on occasion—With enthusiasm."

—Peter, *Silent Sky* (p. 16)

Though they seemed to enjoy their time working at the Observatory, the computers liked to poke fun at their low wages and somewhat poor working conditions. One of the ways they did so was with "The Observatory Pinafore," a parody of Gilbert and Sullivan's comic operetta *H.M.S. Pinafore*.

The parody contained lyrics such as:

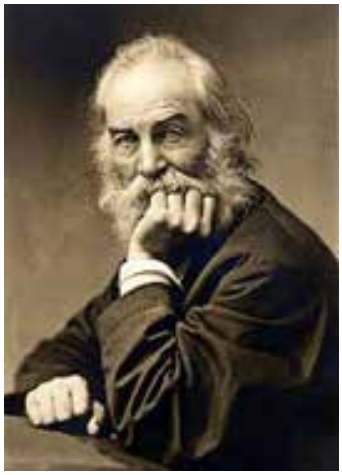
"He must open the dome and turn
the wheel,
And watch the stars with untiring zeal,
He must toil at night though cold it be,
And he never should expect a decent
salaree.
We work from morn till night,
Computing is our duty,
We're faithful and polite,
And our record book's a beauty."

"When I Heard the Learn'd Astronomer"

Henrietta: This. Is the book my father sent me.
Peter: You never opened it?
Henrietta: I was too busy. And then too… ashamed, I think. (*Henrietta opens it—it's a book.*) Collected poems.
Peter: Really? (*She shares it with him.*) Whitman.
Henrietta: My father sent me poems?
Peter: This one's marked.

—*Silent Sky* (p. 58)

"When I Heard The Learn'd Astronomer" was first published in the 1867 reissue of Walt Whitman's poetry anthology *Leaves of Grass*. Though the first edition was published in 1855, Whitman continued to rework and expand the anthology, releasing new editions from 1856 to 1892 (what he would call his "deathbed" edition"). Although the title itself was rereleased, Whitman considered each separate version of *Leaves of Grass* as its own book and republished and reworked it as such, with such poems as "I Sing the Body Electric," "Oh Captain, My Captain" (a tribute to the slain President Abraham Lincoln) and the aforementioned "When I Heard the Learn'd Astronomer" appearing in different editions. Interestingly, *Leaves of Grass* was considered somewhat controversial at the time of its release, as several of the poems within contained themes of sexuality, procreation and intense bodily experiences.



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.

Music

Matthew Vichlach, Sound Designer

Silent Sky focuses on the unsung women of the Harvard Observatory who made monumental contributions to the field of science and astronomy. Thus, it was important that the production designers find a way to represent these women in a way that did them justice and shone a light on their work.

When it came to designing the sound for the show, Matthew Vichlach choose to research the history of female composers.

Intrigued by the dualities inherent in the script, we wanted classical music to reflect the earth and ambient music to help us symbolize reaching for the stars. Diving deeper into the script, it became clear that a piece with such strong women should have featured music composed by women.

Considering the time period, late Romantic composers were selected. Surprisingly, he uncovered a rather large number of composers—about sixty musicians from Europe and North America. Unfortunately, of those sixty very few had work which survived in printed form. And those that were published were not preformed often, or ever recorded. This scarcity proved challenging, but in the end we believe he found pieces that reflected the spirit of these women as they charted the stars! (For a list of music used in the show, check with our box office.)

The Impact of Henrietta Swan Leavitt's Work

Though she does not get half of the credit she deserves and though we will probably never know as much about her as her male counterparts, the impact of Henrietta Swan Leavitt's work is still felt today. Because of her work with the Cepheid variables and her discovery of the period-luminosity relationship, scientists and astronomers were able to use the Cepheids as markers to calculate the distance to objects that were too far to be calculated by other means. This led astronomers such as Edwin Hubble and Ejnar Hertzsprung to use her work to further their own studies in the universe.

To put this in perspective, around the time Henrietta was working at the Harvard Observatory the general consensus among the astronomical community, and indeed the world, was the our earth, solar system and galaxy were all that there were to the universe. Without her discovery, we might still believe that today. In fact, her work is still being used today, with a recent example being the 2012 discovery that the North Star, Polaris (another Cepheid variable), is actually 100 light-years closers to Earth than originally assumed. With her contribution to astronomy and science, Henrietta Swan Leavitt deserves her title as "the woman who discovered how to measure the universe."

"Then a telescope named Hubble, with wings set for space, shows us how vast and beautiful it all is…Because wonder will always get us there…Those of us who insist that there is much more beyond ourselves. And I do. (*A pulsing light surrounds and becomes Henrietta. She is now a blinking star.*) And there's a reason we measure it all in light. (*Blackout—but for stars everywhere.*)

—Henrietta, *Silent Sky* (pp. 61-62)

References / Works Cited

"About Lauren." www.laurengunderson.com.

"About the Collection." Astronomical Photographic Plate Collection (Harvard College Observatory-Plate Stacks). Harvard.edu.

Aceves, Ana V. "Annie Jump Cannon: Star Classifier." Sky & Telescope. skyandtelescope.com. 9 September 2016. Web.

"Annie Jump Cannon." Brooklyn Museum. www.brooklynmuseum.org. Web.

"Annie Jump Cannon Biography." The Biography.com website. www.biography.com. 2 April 2014.

"Annie Jump Cannon: The Queen of Modern Astronomy." Rejected Princesses. www.rejected-princesses.com. Web.

Bartels, Meghan. "How Harvard's vast collection of glass plates still shapes astronomy." Astronomy.com, 1 February 2017. Web.

Bisignani, Dana. "History of Feminism in the U.S.: The Three Waves." The Gender Press. Word Press, 23 January 2015. Web.

"Bloomers." Encyclopedia of Fashion. www.fashionencyclopedia.com.

"A Brief History of the Harvard College Observatory." Department of Astronomy. harvard.edu. Web.

Boissoneault, Lorraine. "The Original Women's March on Washington and the Suffragists Who Paved the Way." Smithsonian. smithsonianmag.com. 21 January 2017. Web.

Camire, Chris. "MRT's 'Silent Sky' brings pioneering woman to life." Lowell Sun. lowellsun.com. 1 November 2017. Web.

Carroll, B. & Ostlie, D., *An Introduction to Modern Astrophysics*. Reading, Massachusetts: Addison-Wesley Publishing Company, 1996.

"Cepheid Variable Stars & Distance Determination." CSIRO. atnf.csiro.au. Web.

Chaisson, E. & McMillan, S., *Astronomy Today*, 2nd edition; Upper Saddle River, New Jersey: Prentice Hall, 1996.

D'Souza, Karen. "Review: 'Silent Sky' at TheatreWorks a radiant look at gender politics." *Mercury News*. mercurynews.com. 20 January, 2014. Web.

Dorey-Stein, Caroline. "A Brief History: The Three Waves of Feminism." Progressive Women's Leadership, 22 September, 2015. Web.

"Edwin Hubble." Biography.com, A&E Television Networks. Web.

"Edwin Powell Hubble—The man who discovered the cosmos." Hubble Space Telescope website: www.spacetelescope.org. Web.

"Essay: Newton vs. Einstein vs. the Next Wave." American Museum of Natural History website.

"Farm Wife, 1900." EyeWitness to History, www.eyewitnesstohistory.com (2007). Web.

"For the Beauty of the Earth." Hymnary.org. Web.

"From Trumpet to iPhone: A Visual History of Hearing Aids." Audicus websute. www.audicus.com. 7 October 2014. Web.

Geiling, Natasha. "The Women Who Mapped the Universe and Still Couldn't Get Any Respect." Smithsonian Institution website. www.smithsonianmag.com. 18 September 2013. Web.

Greene, Nick. "Astronomy: The Science of the Cosmos." ThoughtCo. www.thoughtco.com 8 September 2017. Web.

"The Harvard Computers: From Pickering's Harem to Astronomy's Stars." womanastronomer.com. 1 January 2008. Web.

"HCO: The Great Refractor." Harvard College Observatory. www.cfa.harvard.edu. Web.

Hebert, Phil. "'Silent Sky' gives a starry-eyed scientist her due." *The San Diego Union-Tribune*. sandiegouniontribune.com. 1 May 2017. Web.

Hennessey, Logan. "Oh! Be A Fine Girl—Kiss Me!" Annie Jump Cannon: academics.wellsley.edu. Web.

"Henrietta Leavitt." womanastronomer.com. 1 January 2008. Web.

"Henrietta Swan Leavitt." famousscientists.org. Web.

"Hertzsprung-Russell Diagram." COSMOS—The SAO Encyclopedia of Astronomy. www.astronomy.swin.edu.

Howell, Elizabeth. "Henrietta Swan Leavitt: Discovered How to Measure Stellar Distances." www.space.com. 11 November 2016. Web.

"Interview with Silent Sky Playwright Lauren Gunderson." Austin Playhouse. austinplayhouse.blogspot.com. 21 September 2016. Web.

Jahn, Frank. "Farm Life At The Turn Of The Century." Ebparks.org. Web.

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.

Lavender, Gemma. "Heroes of Space: Henrietta Swan Leavitt." spaceanswers.com. 4 July 2015. Web.

Leaves of Grass. poets.org. Web.

Leaves of Grass (1867). Walt Whitman Archive. whitmanarchive.org. Web.

Mack, P.E. "Strategies and Compromises-Women in Astronomy at Harvard College Observatory 1870-1920." *Journal for the History of Astronomy*. Vol.21, No.1. February, 1990. adsabs.harvard.edu. Web.

"Magellanic Clouds." Cosmos. www.astronomy.swin.edu.au. Web.

Meacham, Andrew. "For better and for worse, 'Silent Sky' challenges audiences." *Tampa Bay Times*. tampabay.com. 6 May, 2016. Web.

Miller, James E. Jr. "Sex and Sexuality." The Walt Whitman Archive. whitmanarchive.org. Web.

"National Women's Party and Militant Methods." National Women's History Museum. crusadeforthevote.org. Web.

"Notebooks and Fly Spankers." The Women Who Mapped The Stars. starmappers.wordpress.com. 16 April, 2017. Web.

"Our History." Radcliffe Institute for Advanced Study at Harvard University. www.radcliffe.harvard.edu. Web.

"Parallax." www.dictionary.com. Web.

"Radcliffe." Harvard University. www.harvard.edu.

Reid, Kerry. "'Silent Sky': Story of women astronomers told with warmth at First Folio." *Chicago Tribune*. chicagotribune.com. 4 April, 2017. Web.

"Rural Life In The Late 19th Century." Library of Congress. Web.

Sobel, Dava. *The Glass Universe: How the Ladies of the Harvard Observatory Took the Measure of the Stars*. New York: Penguin, 2017.

"Statistical Parallax." oxfordreference.com. Web.

Stoudt, Charlotte. "Theater review: 'Silent Sky' at South Coast Repertory." *Los Angeles Times*. latimesblogs.latimes.com. 12 April 2011. Web.

"Types of Variable Stars: Cepheid, Pulsating and Cataclysmic." www.space.com. 28 January 2015. Web.

Whitman, Walt. "When I Heard the Learn'd Astronomer." Poetry Foundation. poetryfoundation.org. Web.

"Williamina Fleming." The Woman Astronomer. womanastronomer.com. 1 January 2008. Web.

"Williamina Paton Stevens Fleming." Distinguished Women of Past and Present. www.distinguishedwomen.com. Web.

"Williamina Paton Stevens Fleming (1857-1911)." Harvard University Library Open Collections Program. www.ocp.hul.harvard.edu. Web.

"The Woman Suffrage Movement." National Women's History Museum. nwhm.org. Web.

"World War I History." www.history.com. Web.