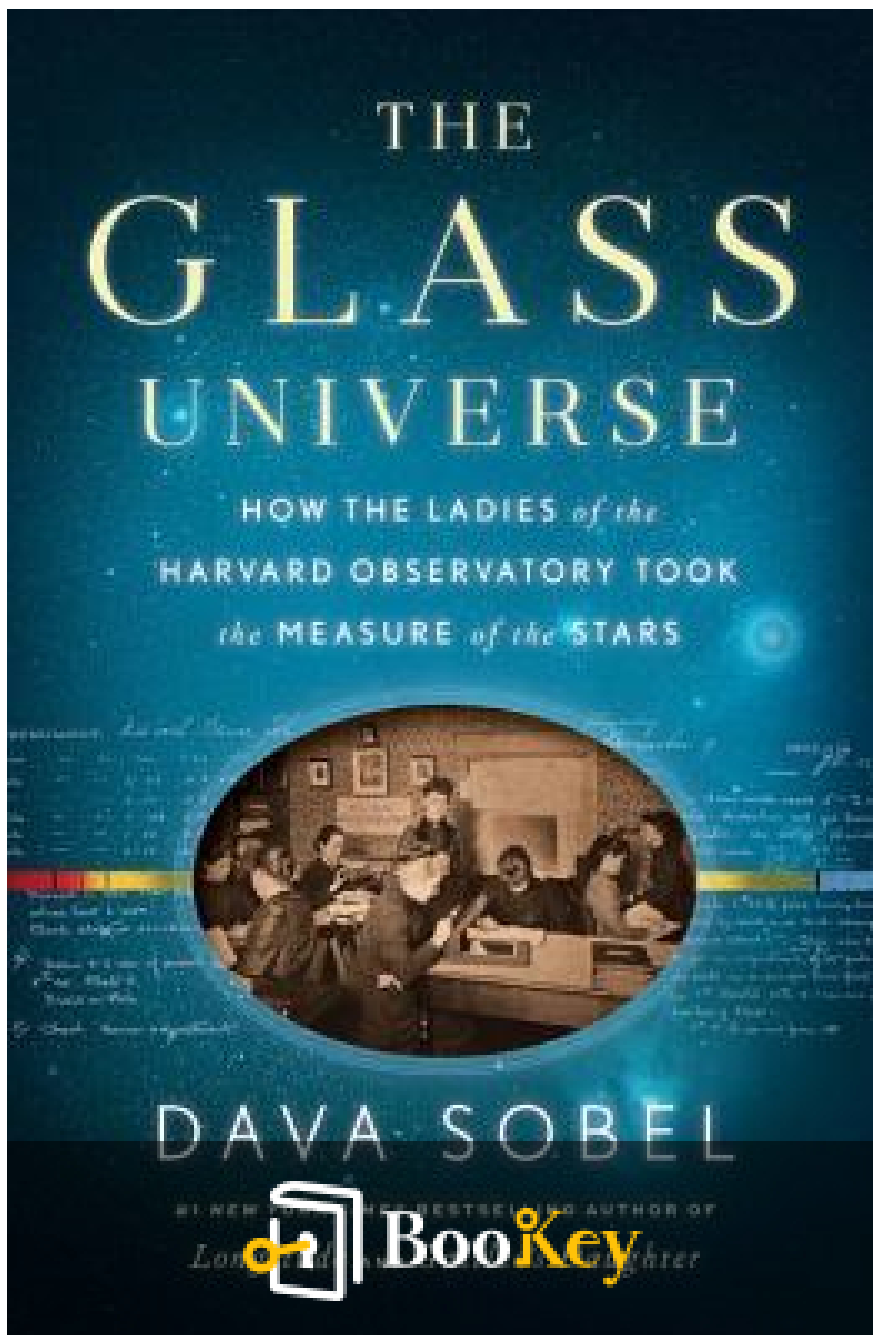


The Glass Universe PDF (Limited Copy)

Dava Sobel



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The Glass Universe Summary

Unveiling the Stars: Women Who Revolutionized Astronomy at
Harvard.

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About the book

In "The Glass Universe," Dava Sobel tells the inspiring narrative of the women who worked at the Harvard College Observatory during the mid-nineteenth century, a time when the field of astronomy was undergoing significant transformation. Originally, this group of "human computers" consisted mainly of the wives, sisters, and daughters of male astronomers, often taking on roles that were instrumental, yet underappreciated. As societal changes emerged and women's colleges like Vassar, Wellesley, and Smith began to produce educated women, the observatory welcomed these graduates into its ranks, further enriching its talent pool.

The introduction of photography marked a pivotal moment in astronomy, as it allowed for more precise data collection than the manual methods previously employed. This shift enabled the women at the observatory to transition from simple calculations to the intricate analysis of glass photographic plates—resulting in groundbreaking astronomical discoveries. With the support of Anna Palmer Draper, a pivotal benefactor who recognized their potential, these women embarked on projects that involved identifying the composition of stars, developing systematic classification methods, and measuring cosmic distances.

Among the central figures in this movement were Williamina Fleming, who made significant contributions to the classification of stars; Annie Jump

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Cannon, who refined these classifications and developed the famous Harvard Classification Scheme; and Cecilia Helena Payne, who proposed innovative theories regarding stellar composition that fundamentally altered our understanding of the universe. Together, their efforts not only advanced the field of astronomy but also paved the way for future generations of women in science, challenging the constraints of a male-dominated profession and leaving an indelible mark on the scientific community.

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About the author

Dava Sobel, a prominent science journalist and author, has captivated readers with her ability to blend scientific concepts with compelling narratives. Her academic journey began at the Bronx High School of Science, a prestigious institution known for its emphasis on STEM education. She continued her studies at Antioch College and the City College of New York, ultimately earning her Bachelor of Arts from the State University of New York at Binghamton in 1969. Over her extensive career, Sobel has contributed to renowned publications such as *Audubon*, *Discover*, *Life*, and *The New Yorker*, showcasing her expertise in making complex scientific ideas accessible to the general public.

One of her most recognized works, **Longitude**, delved into the history of the quest for determining longitude at sea, highlighting the significant contributions of figures such as John Harrison, a self-taught clockmaker whose development of precise timekeeping mechanisms revolutionized navigation. This book not only established her as a distinguished author but also earned her a place in the scientific community, culminating in an asteroid being named in her honor (30935 Davasobel). Her collaborations, including the book **Is Anyone Out There?** with astronomer Frank Drake, further emphasize her commitment to exploring humanity's relationship with science, especially in the context of space exploration.

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In recognition of her impactful contributions to literature and science, Sobel received honorary doctor of letters degrees from the University of Bath and Middlebury College in 2002. Her unique talent for weaving stories from the fabric of scientific inquiry has left an indelible mark on both literature and science communication.

As she moves forward in her writing career, Sobel continues to illuminate the beauty of scientific discovery, inviting readers to engage with the wondrous complexities of the natural world.

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Chapter 1 Summary: Mrs. Draper's Intent

CHAPTER ONE: Mrs. Draper's Intent

The Draper Mansion and a Celebrated Gathering

On the evening of November 15, 1882, the Draper Mansion glowed brightly with electric lights as Dr. and Mrs. Henry Draper hosted a prestigious dinner for members of the National Academy of Sciences. Among the attendees was the renowned inventor Thomas Edison, who once shared a camping experience with Dr. Draper while observing a solar eclipse. Mrs. Draper reveled in her electrified home, using the occasion to highlight the convergence of science and domestic hospitality while catering to her husband's ongoing passion for astronomy.

Mrs. Draper's Support for Astronomy

Introduced to the wonders of astronomy through her husband, Anna Palmer Draper developed her own fascination for the field. Although her husband faced declining health, he remained engaged with his guests, discussing his innovative work with Edison's electric lamps. Tragically, just five days after the dinner, Henry Draper passed away due to health complications that arose from a hunting trip to the Rocky Mountains.

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Continuing Henry's Legacy

Determined to honor her late husband's contributions, Mrs. Draper sought to continue his astronomical legacy. She reached out to Professor Edward Pickering, sharing her commitment to undertake Henry's research in stellar photography and spectroscopy, despite her own feelings of inadequacy. To support her efforts, she planned to enlist assistants who could help carry forward the crucial work her husband had started.

Professional Collaboration and Challenges

Pickering offered his expertise and understanding of the significant challenges Mrs. Draper would face as she assumed the mantle of her husband's work. Together, they set out to analyze the stellar spectra captured in Henry's photographs, while Mrs. Draper adjusted to life as a widow, motivated to uphold her husband's remarkable contributions to the field of astronomy.

Observatory Visits and Discoveries

During her visits to the Harvard Observatory, Mrs. Draper was warmly received by the Pickering family and was immersed in the professional practices employed there, which often contrasted with her husband's

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pioneering techniques. In the context of financial pressures, Pickering aimed to broaden astronomical research through contributions from volunteers, including women observers, fostering a more inclusive scientific community.

Analysis of Stellar Spectra

As Pickering delved into the glass plates created by Henry Draper, he recognized the tremendous opportunities presented by photographic techniques in studying stellar spectra. This realization sparked conversations about publishing their findings to establish precedence and to disseminate Henry's innovative techniques across the astronomical community.

A Monumental Collaboration

The collaboration between Mrs. Draper and Pickering evolved into a significant partnership as they worked to create a photographic catalog of stellar spectra in honor of Henry. Generously financing this project, Mrs. Draper ensured that her husband's extraordinary contributions to astronomy would not only be preserved but also expanded, paving the way for future generations of scientists.

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Chapter 2 Summary: What Miss Maury Saw

Chapter Two: What Miss Maury Saw

In the late 19th century, the Harvard College Observatory underwent a transformative phase thanks to the funding from the Henry Draper Memorial. This financial boost led to the construction of a dedicated building for Dr. Draper's telescope in 1886, positioning the observatory at the forefront of astronomical research. The introduction of advanced instruments, notably the 11-inch Draper telescope and an 8-inch Bache telescope, allowed the observatory to pivot towards spectral photography, focusing on understanding the physical nature of stars.

During this period, the field of astronomy was rapidly evolving, particularly in the area of spectroscopy—a technique that enables the analysis of a star's light to determine its chemical composition. The groundwork for this was laid by astronomers like Joseph von Fraunhofer and the duo of Robert Bunsen and Gustav Kirchhoff, whose pioneering studies illuminated the importance of spectral lines in identifying celestial bodies' characteristics. Building on this legacy, Edward Pickering, the observatory's director, recognized a unique opportunity to harness the talents of women in science, encouraging them to engage with the glass plates produced by the newly installed telescopes.

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Significant advancements were made in capturing stellar spectra, thanks to Pickering's innovative modifications of prism usage in telescopes. This enhancement allowed multiple spectra to be gathered in a single exposure, creating a vast archive of stellar images. Early contributors like Nettie Farrar and Williamina Fleming were instrumental in analyzing these spectral data, thereby laying the foundation for a systematic classification of stars.

A standout figure in this narrative is Antonia Maury, a Vassar College graduate and the niece of Henry Draper, who joined the team in 1888. With a focus on fine-tuning the study of star spectra, Maury examined the spectrum of Vega, uncovering over a hundred lines that expanded the understanding of stellar characteristics beyond previous efforts.

Through her meticulous work, Maury began to challenge the established classification systems, advocating for a more detailed and nuanced approach to categorize stars. Notably, her exploration of the star Mizar suggested it might be a double star or a spectroscopic binary, illustrating the evolving nature of stellar classification and underscoring her vital contributions to the field.

The chapter also highlights the expeditions orchestrated by Pickering and his team to identify optimal locations for high-altitude observatories, aimed at minimizing atmospheric distortion in observations. These efforts ultimately

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facilitated the establishment of an auxiliary station, significantly advancing the observatory's research capabilities.

By 1890, the collaborative efforts of the observatory staff culminated in the publication of the "Draper Catalogue of Stellar Spectra," marking a significant milestone not just in astronomy but also in recognizing the invaluable contributions of women scientists like Maury and Montina, who gained both acknowledgment and career advancements from their work. Maury's achievements solidified her standing within a male-dominated field and amplified her influence within the scientific community.

In conclusion, this chapter reflects the rise of women in astronomy during the late 1800s and emphasizes the transformative effects of photography and spectroscopy in understanding stars. Antonia Maury emerges as a pioneering figure, symbolizing the burgeoning contributions of women to this scientific frontier.

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Chapter 3 Summary: Miss Bruce's Largesse

CHAPTER THREE: Miss Bruce's Largesse

The chapter opens with the ambitious plans of Edward Pickering, who sought to establish Harvard's Southern Hemisphere observatory. Central to this vision was the Bruce telescope, a state-of-the-art 24-inch telescope with a hefty price tag of \$50,000. To bring this dream to fruition, Pickering turned to Catherine Wolfe Bruce, an affluent Manhattan heiress who had developed a newfound interest in astronomy. Despite her lack of experience with telescopes, she was inspired by the prospect of groundbreaking astronomical discoveries that the telescope could facilitate.

Catherine Wolfe Bruce, known for her role as a patron of the arts, made a significant contribution to the project after engaging in correspondence with Pickering. She was driven by the potential advancements in astronomical research, despite skepticism from established figures like Simon Newcomb. Through her persistence and willingness to learn about the field, she pledged not only the necessary funds for the telescope but also a further \$6,000 to support emerging astronomers worldwide.

However, the road to construction was fraught with challenges. The glassmaker Mantois in Paris faced hurdles in producing the telescope's lens,

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prioritizing other orders which delayed the entire project. This was a setback for the observatory, which was supposed to be setting new standards for astronomical research.

Amid these delays, William H. Pickering took charge of the Southern Observatory in Arequipa, Peru in January 1891. His focus on establishing a formal structure and improving personal facilities threatened his commitment to ongoing research, as he struggled to share vital photographic data back to Cambridge.

Despite the telescope setbacks, Mina Fleming emerged as a central figure in organizing thousands of glass plates—each documenting stars. Her systematic approach allowed for significant discoveries, particularly in identifying variable stars, thus enhancing the observatory's reputation for research excellence.

In contrast, Antonia Maury found herself grappling with her star classification duties. Her relationship with Pickering became strained as she attempted to juggle teaching and research. This imbalance took a toll on her health, ultimately leading to her departure from the observatory.

As the narrative progresses, the long-awaited telescope lenses finally arrived in early 1892, ushering in the next phase of the project as they prepared to grind and polish the lenses into a precise four-element structure. However,

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during this time, the observatory underwent administrative changes, with Solon Bailey appointed to oversee operations.

To safeguard the burgeoning collection of photographic plates critical to their research, Pickering spearheaded the construction of a fireproof building at the observatory. This infrastructure not only protected the scientific artifacts but also marked a significant milestone in the observatory's efforts to preserve its contributions to astronomy.

By late 1893, the Bruce telescope's construction had made considerable advancements, signaling a triumphant phase in the collaboration between Miss Bruce and the observatory staff. Their joint efforts set the stage for future astronomical breakthroughs, solidifying the importance of the Bruce telescope in the scientific community and ensuring its legacy in the field of astronomy.

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Chapter 4: Stella Nova

Chapter Four: Stella Nova

Overview of Novae Discovery and Impact

The chapter opens with a sense of awe surrounding the phenomenon of novae, or "new stars," first documented by astronomers such as Tycho Brahe and Johannes Kepler. Brahe's 1572 observation of a nova marked a transformative moment, challenging centuries-old beliefs about the heavens being fixed and immutable. Fast forward to 1893, when Mina Fleming made a groundbreaking discovery with Nova Normae, the first nova identified through spectral analysis. This was a pivotal moment in astronomy, as it expanded the understanding of variable stars—those that undergo significant brightness changes—thus laying the groundwork for future discoveries in astrophysics.

Mina Fleming's Contribution

Fleming's work was characterized by her meticulous examination of photographic plates, leading to her identification of Nova Normae. This discovery not only earned her recognition but also sparked comparisons with earlier observations of novae, hinting at a deeper relationship between their

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compositions. Her findings underscored the exciting potential for further exploration into other variable stars, marking a significant advancement in astronomical methodology.

Solidifying Scientific Techniques

In this chapter, Edward Pickering emerges as a key figure who began to systematize the classification of variable stars, with novae highlighted for their remarkable behavior of sudden brightness followed by fading.

Although the cause of this behavior remained elusive—initially speculated to be due to stellar collisions—the insights gained from studying these stars reflected the evolving techniques in observational astronomy, particularly through the implementation of photography.

Solon and Ruth Bailey's Contributions

The role of Solon Bailey is particularly emphasized as he manages operations at the Arequipa station. His documentation of celestial phenomena, particularly the rich fields of globular clusters, led to the discovery of numerous variable stars. The chapter also addresses the internal conflicts within the Harvard Observatory, notably between Bailey and Seth Carlo Chandler over the validity of spectral photography as a tool for uncovering variable stars, revealing a broader tension in astronomical research methods.

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Professional and Personal Struggles

As the narrative unfolds, it touches on the professional obstacles faced by Pickering at the observatory and the struggles of Mina Fleming and Antonia Maury, who navigated the male-dominated field of astronomy. Their correspondence reveals personal anxieties as they attempted to secure recognition for their contributions amidst a backdrop of skepticism and criticism.

William Pickering's Pursuits

The chapter notes the career transition of William Pickering from the Arequipa observatory to align with Percival Lowell's Martian studies at the Lowell Observatory. This shift not only marked a personal career pivot but also reflected the divergence in focus between planetary studies and the tumultuous environment of the observatory in Peru.

Bailey's Challenges in Arequipa

Amidst rising political tensions and a civil uprising in late 1894, Solon Bailey takes proactive steps to secure the observatory's facilities, illustrating the intersection of scientific inquiry and societal upheaval. His reflections on the changing environment highlight the impact of external chaos on

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scientific research.

The Arrival of the Bruce Telescope

Towards the end of the chapter, anticipation builds around the arrival of the

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Chapter 5 Summary: Bailey's Pictures from Peru

Chapter Five: Bailey's Pictures from Peru

In this chapter, the narrative centers on Edward Pickering, the director of the Harvard Observatory, who viewed Solon Bailey as a promising successor. As Bailey assumed control of the Arequipa station in Peru, he engaged in various photographic projects that enhanced astronomical research. Meanwhile, Professor Arthur Searle, a reliable presence at Harvard and an experienced photometric researcher, continued to oversee operations at the observatory.

A pivotal development in this era was the remarkable contribution of women to astronomy. Two notable figures are Henrietta Swan Leavitt and Annie Jump Cannon. Leavitt, who faced hearing loss, was tasked with analyzing stellar magnitudes from glass photographs, laying the groundwork for understanding the brightness of stars. In tandem, Cannon, also dealing with hearing difficulties, actively observed variable stars, marking a significant milestone as the first female assistant to utilize a telescope for direct observations. Their work not only advanced scientific knowledge but also shifted societal norms surrounding women's roles in the field of astronomy.

Catherine Bruce, a key philanthropist, played a critical role in supporting

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astronomical research. She expressed her gratitude to Pickering for his efforts in Peru after receiving prints of Bailey's stellar discoveries. Bruce established a prestigious gold medal for outstanding achievements in astronomy, making it accessible to all astronomers, regardless of gender.

The chapter highlights the scientific advancements resulting from the operational Bruce telescope. This innovative device produced detailed photographic charts that outclassed previous catalogues, igniting debates over the credit for discoveries made from its imagery—a reflection of the competitive dynamics in observational astronomy.

Additionally, Antonia C. Maury earned recognition for her pioneering work in stellar classification, contributing the first publication authored by a woman to the *Annals of the Harvard College Observatory*.

The chapter also introduces the Eros Campaign, led by Seth Carlo Chandler, which aimed to track a fast-moving asteroid named Eros on its approach to Earth. This campaign provided a unique opportunity to measure the astronomical unit, the fundamental distance of Earth from the Sun.

Catherine Bruce's passing in March 1900 left a profound impact on the scientific community, with her obituary recognizing her humanitarian efforts and the significant advancements in astronomy attributed to her philanthropic contributions.

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Overall, Chapter Five underscores the collaborative spirit and the essential contributions of women in early astronomy, while illustrating the institutional support that fueled the remarkable advancements at the Harvard Observatory.

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Chapter 6 Summary: Mrs. Fleming's Title

Chapter Six: Mrs. Fleming's Title

As the 20th century approached, Mina Fleming became a pioneering figure in astronomy. In 1899, she was appointed curator of astronomical photographs by Edward Pickering, making her the first woman to hold any title at Harvard's observatory and university. This groundbreaking role exemplified the changing societal attitudes toward women in science, and Fleming's contributions were soon immortalized in a time capsule reflecting life on campus, emphasizing her collaborative work with a dedicated group of female astronomers.

At the observatory, Fleming's daily life revolved around the classification and measurement of stars, a task she undertook with a team of women. While the work was repetitive, she recognized its vital importance to the field of astronomy and the progress they were making together. Balancing these professional responsibilities alongside her domestic duties proved challenging, as the expectations of her family often added to her already significant workload.

Fleming's collaboration with fellow astronomers, including Annie Cannon, who developed a more streamlined system for star classification, marked an

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important evolution in their research. The new classification order not only simplified their tasks but also set the foundation for future astronomical studies. As her work grew more complex, Fleming faced increasing pressure from both her academic commitments and her familial obligations, yet her dedication to scientific advancements remained unwavering.

Despite her hard work, Fleming encountered personal frustrations, particularly regarding her salary, which contrasted sharply with that of her male colleagues. Nevertheless, she maintained her passion for research, eagerly anticipating the review of photographs from an upcoming solar eclipse. Although her efforts to gain recognition—such as nominations for the Bruce Medal—did not always meet with success, her contributions earned her respect within the scientific community, largely thanks to Pickering's support highlighting her significant discoveries.

The chapter also portrays the vital support network Fleming had within the observatory. Mrs. Draper, a key ally, organized events that fostered camaraderie among the women, reinforcing solidarity amid the evolving landscape of opportunities and challenges faced by women in the field. Through this lens, the narrative captures a period marked by both accomplishment and the systemic barriers that hindered women from receiving equal recognition and compensation in their scientific endeavors.

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Chapter 7 Summary: Pickering's "Harem"

Chapter Seven: Pickering's "Harem"

Recruitment and Expansion at Harvard Observatory

The early 1900s saw a surge in demand for computing positions at the Harvard Observatory, prompting Mrs. Fleming to receive a wave of applications from women eager to volunteer. However, she was cautious about unpaid work, understanding that it could create unwarranted obligations. The economic landscape was tight, making openings rare until a significant turning point in 1903, when Pickering was authorized to hire ten new computers, thanks to a \$2,500 grant from the Carnegie Institution. Acknowledging the importance of this funding, Pickering emphasized the value of the observatory's extensive photographic collection when he communicated with Andrew Carnegie, framing it as essential for future astronomical discoveries.

Progress in Astrophysics

The newly appointed "readers" at the observatory began analyzing patrol plates—photographic records capturing the night sky—leading to the identification of new and previously unrecognized celestial bodies. Pickering

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eagerly reported these findings to Carnegie, showcasing the unique perspective that their photographic archives offered and underscoring the potential for groundbreaking insights into astrophysics.

Challenges for Mrs. Draper

Meanwhile, Mrs. Draper faced a financial crisis as the income from the properties she had invested in the Henry Draper Memorial fund dwindled. Concerned about the allocation of the observatory's funds for various projects, she sought reassurance from Pickering, who promised that all photographs taken with Draper instruments were dedicated to her memorial's cause, thus alleviating some of her worries.

Variable Star Observations

Amidst these developments, Miss Cannon took the lead in studying variable stars at the observatory. Utilizing comparison methods to assess brightness variations, she found valuable contributions from amateur astronomers who shared their observations with Harvard. This collaborative effort culminated in her published work, "A Provisional Catalogue of Variable Stars," which documented significant discoveries, including those made by fellow astronomers Fleming and Bailey.

Henrietta Leavitt's Return

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In a noteworthy development, Henrietta Leavitt returned to the observatory as a reader in 1903, where she focused on establishing the variability of stars within the Orion Nebula. Employing innovative techniques, Leavitt discovered numerous new variable stars, receiving accolades for her impactful findings as she continued to uncover even more.

Increasing Collaboration Among Astronomers

Recognizing the necessity for a unified approach, Pickering championed collaboration among global observatories to systematically catalog variable stars. His vision was ambitious: to explore the vast universe of stars, analyze their behaviors, and draw distinctions between those that remained constant and those that exhibited variability.

Personal Struggles and Donations

The chapter also portrays Pickering's personal challenges as he navigated the deteriorating health of his wife, who passed away in August 1906. Despite his grief, he committed a significant portion of his savings to the observatory, determined to ensure the continuation of vital astronomical research in the face of his personal loss.

Conclusion

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Overall, this chapter captures a transformative era at the Harvard Observatory, highlighting the invaluable contributions of women astronomers, the struggles to secure funding and personnel, and the collective endeavour to expand the horizons of astronomical knowledge during the early 1900s. It emphasizes not only the scientific advancements achieved but also the personal sacrifices made by those involved in this pivotal field.

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Chapter 8: Lingua Franca

Chapter Eight: Lingua Franca

In 1906, a pivotal moment in astronomical research emerged as Henrietta Leavitt, Annie Cannon, and Evelyn Leland embarked on a meticulous search for variable stars, utilizing Harvard's extensive photographic sky maps. Under the guidance of Edward Pickering, the observatory director, the three women systematically charted the night sky, with Leavitt distinguishing herself by discovering 93 new variable stars in her designated sections. Cannon followed with an impressive 31, while Leland contributed 8 discoveries, showcasing the effectiveness of their methodical approach that combined the examination of photographic negatives and positives to differentiate variable stars from their constant counterparts.

Amidst their scientific pursuits, Cannon maintained an active social life, inviting her sister to stay with her and participating in events organized by the Boston College Club. Her contributions were not limited to discoveries; she also revised her "Provisional Catalogue of Variable Stars" and published the more exhaustive "Second Catalogue of Variable Stars" in 1907, marking a significant accomplishment in star cataloging.

In a parallel effort, Mina Fleming employed a distinct methodology focused

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on spectral analysis, leading to the identification of 19 new variable stars in 1907. Her findings were documented in her work "A Photographic Study of Variable Stars," which established criteria for assessing stellar brightness based on nearby stars, further advancing the understanding of stellar behaviors.

Despite their progress, the observatory faced challenges, including threats from fire hazards and potential funding cuts, particularly from influential figure Mrs. Draper. Inclement weather often disrupted operations in Arequipa, prompting Pickering to explore potential new observatory locations in South Africa, with assistant Bailey tasked with evaluating suitable sites.

Collaboration flourished among international astronomers when they gathered at Harvard in 1910, thanks to the initiatives of George Ellery Hale. The discussions, spearheaded by Pickering, centered around the need for a universal photometric standard, culminating in the adoption of Harvard's Revised Photometry as a benchmark, a significant step in standardizing astronomical measurements.

The Solar Union meetings held at Mount Wilson further expanded the conversation to include stellar classification. Pickering's advocacy for the adoption of the Draper system led to the formation of a committee to develop this classification approach, which received broad support from the

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astronomical community.

In conclusion, this chapter highlights substantial advancements in the understanding of variable stars and the formulation of classification systems during this era. The contributions of women astronomers were particularly instrumental, helping to shape the future trajectory of astrophysics and stellar research in profound and lasting ways.

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Chapter 9 Summary: Miss Leavitt's Relationship

Chapter Nine: Miss Leavitt's Relationship

Pickering's Committee and the Draper Classification

As Director Pickering journeys east to Boston, he is engaged in discussion with his Committee on the Classification of Stellar Spectra. They are deliberating a questionnaire designed to gather opinions on the Draper classification system. This system boasts a comprehensive catalogue of over thirty thousand stars, successfully balancing simplicity and complexity without tying it to a singular theoretical framework. However, with the rise of new astrophysicists who favor theory-driven approaches, the need for a more flexible yet rigorous classification has become increasingly evident.

Feedback on the Draper System

The results from the questionnaire reveal substantial support for the Draper system, yet some astronomers criticize its alphabetical designations. They argue that these lack the evocative imagery seen in other classification methods. The debate is further fueled by differing opinions on how well the system reflects stellar evolution, with advocates like Miss Maury pushing for a classification that mirrors the life cycle of stars.

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Cannon and Fleming's Contributions

Two key players in the advancement of the Draper classification are Miss Cannon and Mrs. Fleming, who diligently work on reclassifying old spectra through innovative photographic techniques. Unfortunately, tragedy strikes when Mrs. Fleming's health deteriorates, leading to her passing in May 1911. Her death leaves a significant void in the observatory community, highlighting the challenges faced by women in the field.

Miss Cannon's New Responsibility

In the wake of this loss, Miss Cannon steps up to take on many of Mrs. Fleming's responsibilities. Despite her lack of formal recognition from Harvard University, she perseveres in refining the Draper system, demonstrating remarkable dedication to the classification of celestial bodies.

Volunteer Observers and AAVSO Formation

By 1911, Pickering's network of volunteer observers has expanded, reaching across the Northeast United States and beyond, prompting the formation of the American Association of Variable Star Observers (AAVSO). This organization emerges as a response to the need for better organization among variable star observers, creating a vital support system for advancing

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astronomical research.

Miss Leavitt's Contributions to Variable Stars

After the death of her father, Miss Leavitt returns to her work at the observatory, immersing herself in her ongoing research on variable stars found in the Magellanic Clouds. Her groundbreaking findings elucidate a crucial relationship between the period of variation in these stars and their intrinsic brightness. This discovery holds significant implications for measuring distances across the galaxy, laying the groundwork for future astronomical inquiries.

Miss Harwood and the Maria Mitchell Association

In 1912, the Nantucket Maria Mitchell Association takes a vital step in promoting women's contributions to astronomy by establishing its first astronomical fellowship. This honor is awarded to Margaret Harwood, a Harvard computer who has made noteworthy advancements in astronomical research at both Harvard and the Nantucket observatory.

Pickering's Observations and the Expansion of Astronomy

Meanwhile, William Pickering persists in his solitary observatory work in Jamaica. Although his behavior grows increasingly eccentric, his dedication

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underscores a broader narrative within the field. The contributions of pioneering women like Miss Cannon, Miss Leavitt, and others during this transformative period in astronomy are marked by their resilience and commitment to advancing scientific understanding.

Miss Cannon's European Tour and Committee Work

Representing her field on an international stage, Miss Cannon attends various conferences, where her efforts to champion female contributions in astronomy are recognized. She plays a vital role in promoting the continued evolution of the Draper classification system within the global scientific community, ensuring that the strides made by women in astronomy gain the recognition they deserve.

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Chapter 10 Summary: The Pickering Fellows

Chapter Ten: The Pickering Fellows

Holiday Greetings and Classifications

In 1913, the Harvard College Observatory sent out holiday cards featuring a gold star that symbolized five essential stellar data points. At the forefront of this classification effort was Annie Cannon, who made a remarkable impact by categorizing around five thousand stars each month. Cannon not only reinvigorated existing star categories but also devised a mnemonic strategy to handle the complexities of alphabetical organization in star classification.

Recognition and Collaborations

Cannon's stellar contributions earned her admiration from the Royal Astronomical Society, solidifying her influential role in astronomy. Meanwhile, Henrietta Leavitt, famed for her pioneering research on Cepheid variables, notably established the period-luminosity relationship that would later revolutionize distance measurement in space. Although Leavitt lacked formal accolades, her work inspired many, including the young astronomer Harlow Shapley, who was encouraged to delve into the study of globular clusters, extending the relevance of Leavitt's discoveries.

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World War Impacts on Astronomy

The onset of World War I severely disrupted European astronomical research, placing a greater responsibility on institutions like the Harvard Observatory. Edward Pickering, the observatory's director, urgently sought funding to sustain crucial research during these tumultuous times. The passing of Anna Palmer Draper, a significant financial patron, ultimately provided a critical boost, allowing her legacy of supporting astronomical exploration to continue.

Miss Harwood's Journey

Margaret Harwood found herself presented with an exciting opportunity to advance her studies at the Lick Observatory while contemplating a teaching role. Ultimately, she was appointed as the director of the Maria Mitchell Observatory, which enabled her to pursue her astronomical research further, fostering a new generation of female astronomers in a male-dominated field.

Shapley's Contributions and Findings

Harlow Shapley debuted as a leading figure in the examination of globular clusters, deepening understanding of the cosmos and the significance of Cepheid variables. His research fundamentally reshaped perceptions of our

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solar system's location within the Milky Way galaxy, suggesting it occupied a more peripheral position than previously believed, thus expanding our understanding of the universe's vast structure.

Post-War Scientific Relationships

As the war concluded, Edward Pickering championed the restoration of international scientific collaborations, striving to reintegrate American astronomy with its European counterparts. However, his unexpected death in February 1919 brought an end to a transformative period in astronomy, having led Harvard College Observatory for 42 years and leaving a profound impact on the field.

Legacy of Edward Pickering

Remembered for his remarkable organizational skills and unwavering support for astronomers, Pickering inspired a collaborative ethos that transcended national borders. His extensive work with photographic plates at Harvard not only advanced astronomical research during his lifetime but also ensured that his influential legacy continued to guide future generations of astronomers.

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Chapter 11 Summary: Shapley's "Kilo-Girl" Hours

Chapter 11 Summary: Shapley's "Kilo-Girl" Hours

Introduction of Mary H. Vann and New Nova Discovery

Mary H. Vann, the inaugural Edward C. Pickering Fellow, dedicated her research to novae using the extensive collection of Harvard glass plates. Her groundbreaking work led to the identification of Nova Aquilae 1918, which garnered attention as the brightest nova observed since the invention of the telescope. This discovery not only showcased the potential of photographic techniques in astronomy but also set the stage for further breakthroughs in stellar research.

Dorothy W. Block and the Great New Star

Following Vann, Dorothy W. Block emerged as the second Pickering Fellow, channeling her efforts into the photographic analysis of variable stars. Her investigation yielded the discovery of the Great New Star in Aquila, enhancing her status in the field. Block became a trailblazer, earning the distinction of being the first woman granted permission to operate the 40-inch telescope at Yerkes Observatory, a significant achievement in an era when women faced substantial barriers in scientific fields.

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Antonia Maury's Selection and Contributions

Antonia Maury, who applied for the next fellowship, arrived with an impressive background that marked her as a key figure at Harvard Observatory. Despite being older than her peers, Maury quickly established herself as an invaluable contributor through her concentrated studies on spectroscopic binaries, reinforcing the role of women in astronomy.

Demand for the Henry Draper Catalogue

The work of Harlow Shapley, particularly his studies on cluster structures, underscored an urgent need for the ongoing Henry Draper Catalogue. However, progress was hampered by a labor strike, delaying the essential classification of stars that Shapley's research depended upon.

Shapley's Expanding Galaxy Theory

Challenging prevailing beliefs about the Milky Way's position in the universe, Shapley argued for its status as a massive galaxy rather than just one among many. His innovative approach involved using measurements from B-type stars to calculate distances, which fostered a new understanding of the galaxy's scale.

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The Debate Over Extragalactic Existence

A pivotal moment in Shapley's career was his public debate with Heber D. Curtis regarding the nature of spiral nebulae. Shapley maintained that these structures were part of the Milky Way, while Curtis posited they were separate galaxies. This discourse not only captivated the public but also highlighted the scientific community's divergence on the nature of the universe.

Women Voting and Notable Achievements

With the ratification of the 19th Amendment, women in the U.S. celebrated their newly acquired voting rights. Influential astronomers like Annie Jump Cannon used this milestone to underscore the importance of women's contributions in science, reflecting a broader societal change towards gender equality.

A. Grace Cook's Observational Work

The fourth Pickering Fellow, A. Grace Cook, specialized in meteor observation and other celestial phenomena in England. Her solitary work contributed valuable data to the field, illustrating the dedication and perseverance of women scientists during that time.

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Shapley's Leadership and Cannon's Support

As Shapley assumed directorship at the Harvard Observatory, he significantly advanced star classification research by collaborating with Cannon. He also initiated public engagement programs at the observatory, fostering greater interest in astronomy and broadening the audience for astronomical discoveries.

Challenges and Triumphs in Academia

Shapley navigated various challenges, including the eccentric claims of William Pickering and the looming health crisis of Henrietta Leavitt. Despite these obstacles, he established himself as a prominent figure in astronomy, gaining respect and recognition within the academic community.

Final Reflections on International Collaboration

During a pivotal moment in international astronomy, Shapley took part in the inaugural assembly of the International Astronomical Union. His advocacy for collaboration among scientists across nations highlighted Harvard's leading role in the evolution of astronomical research, promoting a spirit of global scientific inquiry.

Conclusion

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Amidst a backdrop of challenges and transforming perceptions of the universe, Shapley solidified his leadership at Harvard Observatory. His contributions, along with the rising influence of women in science, shaped the future trajectory of astronomical study and set the foundation for collaborative international research efforts.

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Chapter 12: Miss Payne's Thesis

Chapter Twelve: Miss Payne's Thesis

Shapley's Transition and Aspirations

Harlow Shapley transitioned from his role at Mount Wilson Observatory to become the director of Harvard Observatory, where he envisioned broadening the institution's educational mandate. Recognizing the need for greater female representation in astronomy, he took a significant step by recruiting Adelaide Ames as his first graduate assistant, marking an important moment in the advancement of women in the field.

Adelaide Ames and Her Contributions

Adelaide Ames, a talented graduate from Vassar College, joined Shapley's team as the first Pickering Fellow. Her role centered on calculating distances to stars within the Milky Way, and her exceptional efficiency and dedication quickly earned her respect, culminating in her co-authoring a noteworthy research paper with Shapley.

Cecilia Helena Payne's Journey

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Cecilia Payne, who studied at Newnham College in Cambridge, discovered her passion for astronomy after attending a lecture by the renowned scientist Arthur Eddington. Despite societal skepticism regarding women in the sciences, Payne's determination led her to join Shapley's team at Harvard, where she focused on spectral analysis—a technique crucial for understanding the composition of stars.

Collaboration and Inspiration

At Harvard, Payne formed a strong friendship with Ames, creating a supportive dynamic as they worked on their respective projects. Under Shapley's mentorship, Payne was encouraged to pursue her Ph.D.—a remarkable feat in a time when women faced significant challenges in academia.

Scientific Breakthroughs

Payne's groundbreaking research merged atomic theory with astronomy, allowing her to analyze stellar spectra and temperatures in new ways. Her findings demonstrated that while stars share similar elemental compositions, there were surprising proportions of hydrogen and helium, igniting discussions within the scientific community.

Rewards and Recognition

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Cecilia Payne made history by obtaining Harvard's first Ph.D. in astronomy with her innovative dissertation titled "Stellar Atmospheres." Shapley recognized the importance of her work by publicizing her thesis, which drew acclaim from esteemed scientists and solidified Payne's place in the field.

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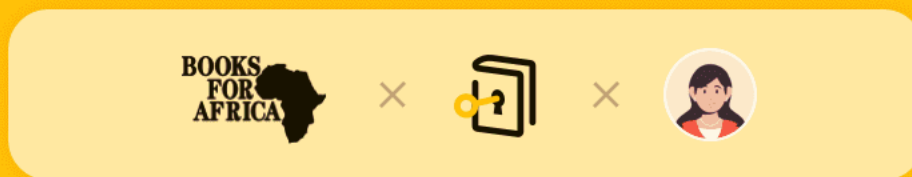




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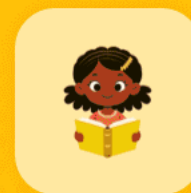
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Chapter 13 Summary: The Observatory Pinafore

CHAPTER THIRTEEN: The Observatory Pinafore

Cecilia Payne's Journey

In this chapter, we delve into Cecilia Payne's thriving life as she balances her burgeoning scientific career with her new domestic role. Settling into her apartment, she aims to challenge the widespread notion of women's inferiority in science, embracing her individuality while affirming that gender should not dictate one's capabilities. The Harvard Observatory, under the guidance of progressive figures like Annie Jump Cannon, promotes an environment where women can flourish, proving that scientific achievement and domesticity are not mutually exclusive.

Martha Shapley as Paragon of Domesticity

Martha Shapley, the wife of the observatory's director, Harlow Shapley, represents the embodiment of this balance. Despite the demands of raising four children, she remains an active participant in the scientific community, contributing to research and maintaining the observatory's tradition of hospitality. Her success earns her the affectionately referred title of the "first lady" of the observatory.

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Evolution of Female Roles in Astronomy

By 1925, the Harvard Observatory has transformed significantly, moving beyond its early hires to showcase a new generation of women engaging in astronomy at higher educational levels. The emergence of innovative roles, such as guest researcher for Priscilla Fairfield, signals a shift toward a more inclusive research community. Harlow Shapley advocates for the advancement of graduate education in astronomy for both men and women, successfully securing funding for essential fellowships.

Harvard's Growing Community and Scientific Pursuits

With an emphasis on impactful research and outreach, the Harvard Observatory extends its reach by establishing southern sky observation facilities in South Africa. Harlow Shapley, in addition to his significant workload, seeks to enhance the observatory's reputation within the broader scientific community through diligent research efforts.

Cecilia Payne's Rise and Challenges

In 1927, Payne transitions to a salaried position, assuming responsibility for overseeing publications and mentoring graduate students. Despite her significant accomplishments, President Lowell obstructs her path to a

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professorship, illustrating the persistent barriers women face within academics. Nonetheless, Payne continues to research stellar luminosity, making meaningful contributions to the understanding of celestial phenomena.

International Astronomical Union and New Relationships

Payne and her colleague Fairfield find themselves at the International Astronomical Union (IAU) assembly in Leiden, where they experience firsthand the global nature of astronomy. This pivotal assembly facilitates new collaborations and personal connections, setting the stage for Fairfield's romantic involvement with Bartholomeus Jan Bok.

Contributions to Astronomy and Recognition

As the observatory flourishes under Shapley's leadership, he recognizes the critical contributions of his colleagues, advocating especially for Annie Jump Cannon's legacy. The increased collaboration and productivity at the observatory bolster its esteemed place in the scientific community, solidifying its reputation as a center for astronomical research.

Legacy of Women in Astronomy

As societal norms evolve, married women in astronomy begin to maintain

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their professional careers without forgoing family life. This shift is exemplified by graduate students like Helen Sawyer and Margaret Walton, who successfully navigate the demands of both personal and professional aspirations in their scientific endeavors.

Reflections on Departure and Advancement

The chapter concludes with a somber reflection on the losses of prominent figures in astronomy, including Solon Bailey and Edward King. Harlow Shapley aspires to ensure that their contributions endure while embedding a commitment to equality and professionalism in future astronomical pursuits. He aims to chart a course for growth that honors the past while promoting an inclusive future.

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Chapter 14 Summary: Miss Cannon's Prize

Chapter 14: Miss Cannon's Prize

Observatory Festivities and Total Eclipse

In September 1932, Harlow and Martha Shapley were busy preparing for the triennial assembly of the International Astronomical Union at Harvard, strategically timed to coincide with a total solar eclipse. While this event offered a prime opportunity for astronomical research, it also posed the challenge of unpredictable weather. Harlow trusted his graduate student, Adelaide Ames, to oversee hospitality arrangements for the esteemed astronomers attending.

Adelaide Ames' Untimely Death

Tragedy struck when Adelaide Ames drowned during a canoeing accident while on vacation. Her loss deeply affected the observatory community, prompting Shapley and others to search for her and subsequently assist with her funeral arrangements. Among those grieving deeply was Miss Cannon, who had lost a cherished colleague and friend.

Women's Advancements in Science

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The historical landscape for women in science had begun to shift, notably illustrated by the Association to Aid Scientific Research by Women awarding the 1932 Ellen Richards Research Prize to Dr. Helen Dean King and Annie Jump Cannon herself. With the association feeling it had achieved its mission, it decided to dissolve. However, Cannon was determined to continue championing women in astronomy by establishing the Annie Jump Cannon Prize to support aspiring female astronomers.

Total Eclipse Observations

The total solar eclipse drew crowds of scientists and tourists, with some teams successfully capturing valuable observations near Harvard, while others faced disappointing weather. During the subsequent Cambridge conference, astronomers exchanged their experiences, and Miss Cannon was celebrated for her contributions, marking a growing acknowledgment of women's roles in science.

Cecilia Payne's Grief and Growth

Devastated by Ames' death, Cecilia Payne reflected on her own life, inspiring her to become more active in her field. She embarked on a tour of observatories across Europe, where she encountered various challenges but also invaluable connections, including the Russian émigré Sergei

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Gaposchkin.

Cecilia's Marriage and Professional Growth

Despite initial concerns regarding Gaposchkin's situation, Payne played a vital role in securing his refuge at Harvard, which sparked a deeper emotional connection between them, leading to their marriage. Although their union faced scrutiny, it ultimately gained acceptance within the observatory community. Miss Cannon saw great potential in Payne, anticipating her as the first recipient of the newly established Annie Jump Cannon Prize.

Awarding the Annie Jump Cannon Prize

Cecilia Payne's achievements in stellar spectroscopy earned her the inaugural Annie Jump Cannon Prize, symbolizing further recognition for women's contributions to astronomy. The award was highlighted by a beautiful handcrafted piece from a woman jeweler, underscoring the spirit of collaboration among female artisans and scientists.

Miss Cannon's Legacy

As she aged, Miss Cannon continued her work, but her health eventually declined. Upon her death in 1941, tributes poured in, celebrating her

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pioneering spirit and extraordinary contributions to astronomy as a trailblazer for women in science. Harlow Shapley and the observatory announced plans for memorials and fellowships in her honor, ensuring her legacy would endure in the scientific community for generations to come.

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Chapter 15 Summary: The Lifetimes of Stars

Chapter Fifteen: The Lifetimes of Stars

Life at the Observatory During War Years

During the tumultuous 1940s, Cecilia and Sergei Gaposchkin fostered a supportive family atmosphere at the Harvard College Observatory, balancing their scientific pursuits with community engagement. Amid the backdrop of World War II, they involved their children in various recreational activities and maintained a farm to help support local families affected by the war. Notably, they extended their hospitality to a displaced family impacted by Japanese internment and created a discussion group aimed at promoting awareness of pressing global issues.

Astronomy and the War Effort

The war prompted many astronomers to redirect their expertise towards aiding military operations. They played a critical role in calculating ballistic trajectories and teaching celestial navigation, essential skills for wartime strategy. Despite facing challenges such as manpower shortages, research activities at the observatory persisted, particularly in South Africa, ensuring that the spirit of inquiry continued amid the chaos of war.

Research on Variable Stars

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While many colleagues were focused on military tasks, the Gaposchkens remained committed to the study of variable stars. They devoted considerable time to classifying and analyzing thousands of data points, leading to significant discoveries, such as identifying U Scorpii as the first known recurrent nova. This work underscored the importance of archival astronomical plates in advancing the field.

Recognition and Challenges Among Peers

As post-war dynamics shifted, the American Astronomical Society recognized Antonia Maury for her dedicated research on spectroscopic binaries. Meanwhile, the administration led by Harlow Shapley faced scrutiny due to his political views, complicating the observatory's operations during a period of job insecurity and fluctuating funding.

Cecilia's Ascendance and Gender Challenges

Cecilia Payne-Gaposchkin made history by becoming Harvard's first female full professor, a remarkable achievement reflecting her contributions to astronomy. Despite breaking significant gender barriers, she and other women in academia continued to grapple with wage disparities that highlighted ongoing inequalities in the professional sphere.

Legacy of Stellar Classification

The legacy of Catherine Wolfe Bruce, a pivotal figure in astronomy funding, lived on through the establishment of prestigious awards that honor

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outstanding scientists. Over the decades, the observatory witnessed transformative advancements in research methodologies and technology, culminating in the shift from glass plates—once a fundamental tool for astronomers—to modern digital imaging techniques.

The Future of the Observatory's Historical Collection

The Harvard College Observatory's rich collection of glass plates serves as a crucial resource for current and future astronomical research. Recognizing the value of this archive, a digitization initiative was launched to safeguard these historical artifacts, especially following a crisis where a malfunctioning water main threatened their preservation. This commitment to digitizing the plates ensures that invaluable astronomical data remains accessible for generations to come.

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