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# Annie Jump Cannon – The Most Important Woman in the History of Astronomy

## Introduction

Annie Jump Cannon is the most important woman in the history of astronomy. This claim cannot be made lightly. Certainly, there were major contributions from her contemporaries (such as Henrietta Leavitt), from those who came before (consider Caroline Herschel) and from the many women working in astronomy over the last 50 years or so (like Jocelyn Bell). This article will specify how a claim such as "most important" can be made in the field of astronomy. Then we will see how Annie Jump Cannon excelled given this criteria. Finally, we will briefly consider other women astronomers and show how Annie Cannon surpasses them all.

## Criteria for Deciding How "Important" an Astronomer Is

In astronomy, the following accomplishments could be considered important.

1. ***Detailed observations that others can use to produce scientific breakthroughs or formulate testable models of the universe.*** This can include observations accurately made or collections of records such as star catalogs. Tycho Brahe made many observations and kept detailed records. These records were then used by Kepler when he formulated his 3 laws that are still in use today (Pasachoff & Filippenko, 2001).

2. ***Encouraging others to study and to work in astronomy.*** This includes enabling others in this field as well as serving as a role model even after the person has died. It also includes tutoring or educating someone in a specific technique or an area of study. Carl Sagan's *Cosmos* TV series and his books inspired many astronomers.

3. ***Significant additions to the general knowledge or "language" of astronomy***. This might include paradigm changing breakthroughs or entire new theories about the universe. It could also include new tools such as the spectrograph. Einstein's theories of special and general relativity created entire new ways of looking at the universe.

   The problem with the above criteria is that they are quite subjective. How can one say that one person's detailed records are more important than someone else's. If we have the advantage of some historical "spacing", then we can see if those records are being used many years later. It is even more subjective to say someone was inspirational. While Sagan was certainly inspirational to some he was considered overrated by others. And major breakthroughs are rare. We could mention Galileo, Newton and Einstein but does anyone else belong in that category? Probably not.

   So it is tempting to try to come up with a objective metrics that we can use to compare

astronomers. A metric gives a scorecard that can be used to compare others if they can be graded the same way.

4. ***Number of citations***. A person who has published articles may have those articles used as references in other writings. The case can made that the person with more citations must be more important than another.

5. ***Awards received.*** There are awards for scientists (in general) and for astronomers. If two or more astronomers qualify for an award but only one person gets that award, we can say that someone (hopefully one or more experts in the field) has declared that person to be more important. Awards can also include honorary degrees. It is difficult to compare one award to another. Winning a Nobel prize is not the same as a distinguished alumnus award.

6. ***Mentioned in list of historically significant astronomers.*** Everybody likes lists (including this author). Several authors have made lists of women astronomers giving a dozen or more names. A person who makes all (or most) such lists is probably more important than a person who does not. At least the should be true if the person making the list has done their historical duty.

7. ***Popularity***. It isn't fair to use popularity to judge who is the most important woman in the history of astronomy. But we include it here as a possible tie-breaker – only to be used after we have done a decent job with the above criteria.

This article will look at each of these criteria and consider how Annie Cannon compares to other woman astronomers. But first, the problems of being a woman astronomer during Annie Cannon's lifetime is considered and then a background of how events came together to give Annie Cannon a chance.

## Very quick look at women in astronomy before Annie Cannon.

Women in astronomy goes back 4000 years ago to the Sumerians who had women who lead the temple observatories. Notable among these was En' Heduanna. (Howard, 1999). Hypatia's achievements in literature and science were second to none around year 400 CE. She was murdered by the local bishop Cyril in 415 out of jealousy at her accomplishments and fame (Hecht, 2003). Family members provided inroads for some women. Sophia Brahe helped her brother recording his observations. Marie Cunitz helped her husband and translated Kepler's works for a wider audience. Caroline Herschel, William's sister, made many discoveries of her own while helping her brother William. She was given the Gold Medal by the Royal Society in 1828 (Belkora, 2003). Maria Mitchell (1818-1889) was the first American woman astronomer and the first professional woman astronomer.

But women were not totally accepted by the male-dominated science of astronomy when Annie Cannon was alive. When Cannon was eventually given a permanent position at Harvard in 1938, the awarding letter sent to her started "Dear Sir" (Powell, 1998). Even in the 1950's women were told they were not welcome. Margaret Burbidge had a run-in with one fellow astronomer. "He thought I had committed a terrible faux pas by applying. He thought I should have known women were not allowed." (Burbidge, 1991). Vera Rubin was the first woman to legally use the Palomar scope in the mid-1960s (Nichols, 1998). So at the time that Annie Cannon decided she wanted to work in astronomy she needed an opportunity that was not generally available to women.

## How Did Everything Come Together for Annie J. Cannon

The career of Annie Jump Cannon was created from three sources: inspiration, opportunity, abundant work. The inspiration is found in her life story. The opportunity came from a group called the computers. The abundant work would be the analysis of stellar spectra.

### A Short Biography of Annie Jump Cannon

Annie Jump Cannon was born on Dec. 11, 1863 in Dover, Delaware. She was one of 7 children in the Cannon household, the eldest of three daughters. Her father was a shipbuilder and later became a politician. Shortly before she was born, her father played a critical role as a state senator in Delaware. He cast the deciding vote that kept Delaware out of the confederacy as the Civil War began. Annie inherited some political interest from her father. She was a suffragette (NWHF website).

Her mother was the second wife of Wilson Cannon. Her maiden name became Annie's middle name. That was not all that she inherited from her mother. Her mother liked to gaze at the stars at night and she and Annie would do so often (SDS Website).

Annie Cannon went to Wellesley college in Massachusetts – then and now a women's only college. She didn't know she was going to Wellesley until she saw her father taking a bushel of peaches to the Wellesley president's house (Welther, 1993). The weather there was probably a bit colder than what she experienced in Delaware. She contracted scarlet fever. Although she fully recovered, the disease left her partially deaf. She graduated from Wellesley in 1884.

After graduation Annie Cannon returned home. Her interest in star gazing was still strong but there is no record that she did very much about it for 8 years. In 1892 she traveled to Europe to photograph a partial eclipse. But a major event in her life was just around the corner. In the following year, her mother died. At this point it appears that she realized she must get on with her own life. She returned to Wellesley and took a job. In 1894 she became a graduate student in Astronomy. Wellesley College would build a real observatory in 1901 but at this time the best nearby observatory was a few miles to the east in Boston.

So in 1895, Annie Cannon enrolled in Radcliffe which is next to Harvard. Radcliffe was a women's college at the time (now part of Harvard but the Radcliffe Institute still carries the name) but cooperated with Harvard in several areas including Astronomy. Just a year later, Annie Cannon started working at the Harvard Observatory (Slaight, 2000).

In 1897, Annie Cannon wrote her first article with Edward Pickering (Pickering & Cannon, 1897)

In 1907, Annie Cannon finally got the master's degree she started working on in 1894. She continued working at the Harvard Observatory. In addition to her duties as a computer, she took on other responsibilities. In 1911, she became the curator of the Harvard Observatory. This put her in charge of the vast and growing collection of photograph plates at Harvard (Women in Science website).

Annie Cannon classified stars from 1911-1915 and the Henry Draper catalogue would be published in a total of 9 volumes between 1918 and 1924. This is discussed more in Criteria #1.

In 1916 she became the chair of Astronomical Fellowship Committee which oversaw the granting of fellowships to other women astronomers. This is discussed further under Criteria #2.

It was around this time that Annie Cannon made the scientific contribution for which she would be most remembered – the stellar spectra classification system known to many OBAFGKM. This is discussed further under Criteria #3.

She completed her Ph.D in Astronomy from Groningen University in 1921(Women in Science website). She also won many honorary degrees and awards as shown under Criteria #5.

In 1938, Annie Cannon would finally get a permanent position at the Harvard Observatory. In 1941 she finally retires from doing stellar spectra, a task she had been doing for decades (Belkora, 2003).

Annie Jump Cannon died in 1941. She had been ill for some time with complications from heart disease. She was still listed as one of the author's of the Henry Draper catalog extension that was published in 1949 (Cannon & Mayall, 1949).

## Stellar Spectra

The study of stellar spectra began with Newton's demonstration of the splitting of sunlight into component colors in 1666. In 1802, William Wollaston saw that there were some dark lines in the solar spectrum (CSIRO, 2004). Joseph von Fraunhofer also noted some unexplained dark lines in the solar spectrum. He was able to expand the size of the spectrum so that the lines could be carefully mapped (Fraunhofer, 1823). You could not see these dark lines normally but it you spread out the spectrum (using cascading prisms) the lines would become visible.

In the latter half of the 19$^{th}$ century the connection was made between the dark absorption lines in the spectra and the elements that produced them. Kirchhoff and Bunsen (1860) introduced the study of spectra with these words: "…several substances have the property of producing certain bright lines when brought into the flame. A method of qualitative analysis can be based on these lines, whereby the field of chemical reactions is greatly widened…". William Huggins *then* used spectroscopy on stars.

In 1863 Huggins started using the new technology of photography to record the spectra so they could be studied later. The results were unsatisfactory so Huggins put off photographic recording of spectra for a while. In 1872, Henry Draper succeeded in photographing the spectra of Vega. Draper would continue to make other stellar spectrographs until his death in 1882. His widow Anna set up the Henry Draper Memorial fund to continue Henry's survey of stellar spectra. Edward Pickering found that by putting a prism at the front of the telescope, an entire photographic plate of spectra could be photographed (Cannon, 1915).

The number of spectra that needed to be scanned became a small mountain of work. This in turn contributed to the need for the "computers".

## The Computers

Pickering, the director of the Harvard College Observatory, hired many women to do complex data reduction. These women were called "computers". It is said that he hired women only because he could pay them 25% as much as he would have to pay men to do the same job. But at the time, simply the fact that he would hire women was a big deal (Women Astronomer Website, 2005).

But hiring women as computers did not originate with Pickering's so-called "harem" (CFA website). The US Naval Observatory hired Maria Mitchell in the same capacity. And actually it was Anna Draper who

suggested to Pickering that he hire women. The idea that Pickering was hiring women just to get by on the cheap comes from a Pickering himself. "[These women] are capable of doing as much good routine work as astronomers who would receive much larger salaries. Three or four times as many assistants can thus be employed, and the work done correspondingly increased for a given expenditure." – Edward Pickering, 1918 (Weber)

The computers came from a wide range of backgrounds. Williamina Fleming had no background in math, physics or astronomy. In fact, she was Edward Pickering's maid. Apparently, Pickering was so fed up with the work of his assistant that he blurted out that his maid could do a better job. Taking up his own dare he gave Fleming the job and she was indeed a marked improvement. Fleming took over the Henry Draper catalog project in 1886 when the current head left after getting married. In 1899 Fleming took over as curator of the Harvard Observatory photographs, a job that would be turned over to Annie Cannon in 1911 (Nichols & Warnicke).

Another famous computer was Henrietta Swan Leavitt. She discovered that the Cepheid variables had a Period-Luminosity relation which gave astronomers the first standard candle that could be used to determine distances beyond the Milky Way galaxy. Other famous computers included Antonia Maury and Cecilia Payne (Nichols & Warnicke).

## Criteria #1 – Detailed Observations Used By Others

Annie Cannon (with help from Pickering and others) completed the Henry Draper catalogue. "The total number of spectrum classifications by Miss Cannon is … very close to 400,000" (Shapley, 1948). It was found that a spectrum only ¼ mm wide provided "lines [that] are sufficiently well defined to classify stars as faint as the $11^{th}$ to $12^{th}$ magnitude" (Cannon, 1925).

Annie Cannon was able to classify stars very quickly. Although the first volume of the Henry Draper Catalogue would not be published until 1918, Annie completed most of the classification work between 1911 and 1915 (Merrill, 1941).

Cecilia Payne-Gaposchkin said that Cannon's ability at classifying stars was an inexplicable talent. She recognized stars like other people remember faces. "She had amazing visual recall, but it was not based on reasoning. She did not think about the spectra as she classified them – she simply recognized them" (Greenstein, 1993).

Years later, mere months before she died, Annie Cannon was still doing the same kind of work. In 1941, she wrote "At the Observatory, I am classifying, classifying and now getting ready to start on a large piece for Yale Observatory. It will be a job! And will keep several assistants busy doing minor details. Of course I love to do it." - (Weber)

What other women astronomers fit this criterion? Certainly there are the other computers. Henrietta Leavitt not only discovered the P-L relation of Cepheid variables but made many measurements of variable stars and discovered 2,400 of them. Leavitt was profoundly deaf (Singh, 2005).

## Criteria #2 – Helping Others

From 1916 until her death 25 years later, Annie Cannon was chairman of the Harvard Observatory's Astronomical Fellowship Committee. This was the Edward C. Pickering Fellowship given to a woman astronomer. The winners included Antonia Maury, Adelaide Ames and Cecilia Payne (Cannon, 1941). She was particularly instrumental in starting the career of Cecilia Payne-Gaposchkin (Bitterman).

The Annie Jump Cannon award is given to a North American female astronomer within 5 years of receiving her PhD based on outstanding research and promise for future research (AAS website, 2006). Annie Cannon started this award using the money she received from another award (AJNotice, 1966).

Cannon's deafness was a particular inspiration to Henrietta Leavitt who was also deaf (Clark & Clark, 2004).

There were so many accolades for Annie Jump Cannon after she died and several writers tried to summarize her achievements and also her personality. She had a "priceless ability of being good company for all kinds of people … her character, distinguished by modesty and unselfishness, was human nature at its best" (Merrill, 1941). She was called "a continued source of inspiration to all who knew her. This is especially true for women who work in astronomy" (Bok, 1941). Another notice said that besides being a pioneer she was "genuinely interested in all persons" (MMA Notice, 1941).

The argument could be made that talking about how nice Annie Cannon was is completely irrelevant. But there have been times when an uncooperative nature prevented, at least for a while, scientific progress. Fritz Zwicky was a noted astronomer who predicted the existence of dark matter in the 1930's. But his work on this topic was largely ignored because he managed to anger many of his colleagues (Soter & Tyson, 2000). Tycho Brahe made many observations but refused to share them even with his collaborator, Kepler, until Brahe died.

Who else fits this criterion? Cannon was aided by Sarah Frances Whiting who helped many others. Maria Mitchell, the first American woman astronomer, inspired many just by her example. There are many positive role models today including Emma Bakes, Carolyn Porco, Sandra Faber, Wendy Freedman and many others.

## Criteria #3 – Major Breakthroughs

The major scientific breakthrough that everyone attributes to Annie Cannon is the stellar spectra classification system. The first attempt at classifying stars by their spectra was done by Angelo Secchi in the 1860's. His system put stars into broad categories that were called Type I, II or III. (Schlatter, 2006). But it was clear that Secchi's classification system did not give enough information (Cannon, 1929).

Pickering and Fleming created a system based on how strong the Fraunhofer lines were in stellar spectra. The stronger lines were called class A, next was B and so on. The total number of classes was between 14

and 22[1]. Some of these classes were similar but included doubled lines but these doubled lines were probably errors in the equipment.

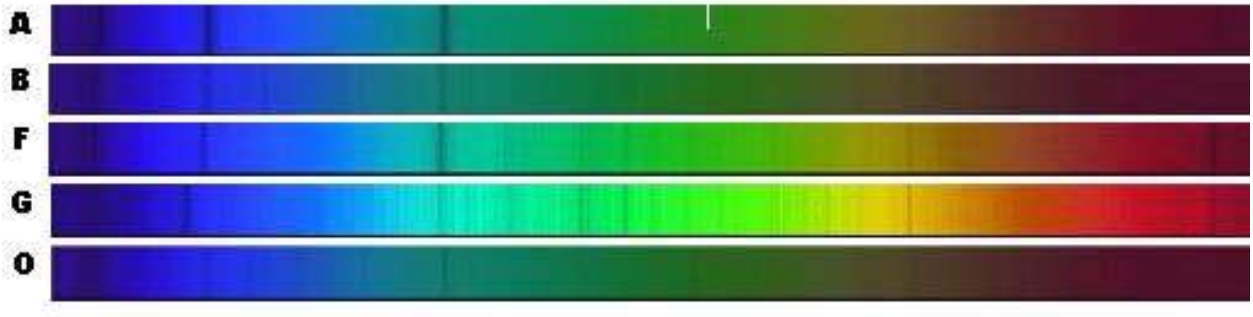


**Figure 1 - Astronomers classifying stellar spectra would work with strips like these. The A star had some very obvious dark bands and few smaller bands. B stars had bands that were a bit less definite. This original ordering was in order of descending strength of the hydrogen lines while Cannon would order them in descending order of temperature (Pasachoff, 2003). (picture from Richmond with some extra processing by the author.)**

Annie Cannon wrote "The evidence that the Orion spectra [Class B] precede the Sirian [Class A] is as good as that the Sirian precede the solar [Class G]. The gradual decrease in the intensities of the Orion lines is accompanied by gradual increase in the hydrogen lines, and by the incoming of faint solar lines, so that in spectra of Classes B8A and B9A, solar and Orion lines are commingled. Hence it was necessary either to interchange the letters B and A of the Draper Catalogue or to place the letter B before the letter A. The alternative would prove confusing. The second presents no real difficulties since the letters are merely symbols to express an observed condition." (Cannon, 1897 cited in Merrill, 1941). After the B and A stars, the next clearly different star classification was the F star. Thus Cannon's new list started as B, A, F. Others would call it "baffling" for this reason (Cannon, 1929). Later, the O stars would be put at the top of the list. Annie Cannon wrote that "it happened again that the natural order of the alphabet must be broken" (Cannon, 1915). The reason for this is that the O stars were found to be similar to the B stars in helium and other absorption lines. This gives a final order of OBAFGKM. Annie Cannon devised the mnemonic device "Oh, be a fine girl, kiss me" to remember the ordering. (Danielson, 2000). When the stellar spectra strips were arranged in this order it looked like the following.

[1] See note on references, the number of classifications seems to be uncertain.

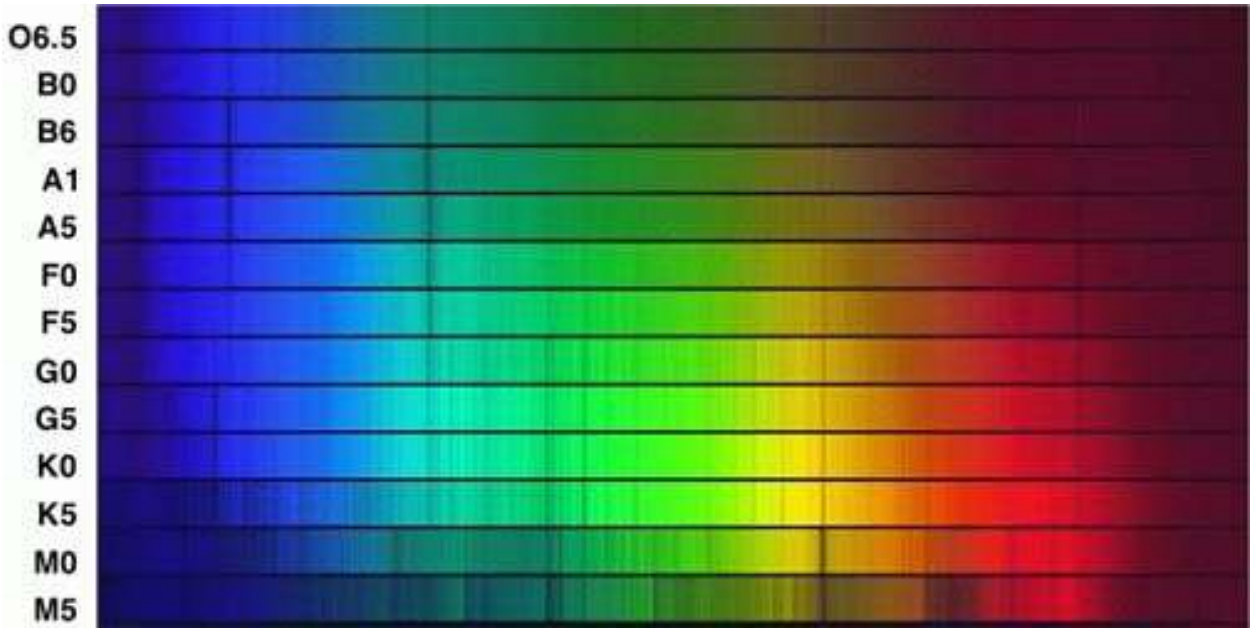


**Figure 2 - When the spectra classes are put into Annie Cannon's order you can follow the brightest portions of the spectrums as it moves from blue to red. Hertzsprung and Russell devised their H-R diagram from this information. You can also see some bands darken and then fade away. The spectra are now ordered by stellar temperatures. (picture from Richmond)**

Annie Cannon said "it was almost as if the distant stars had really acquired speech, and were able to tell of their constitution and physical condition" (Cannon, 1915). This classification scheme was not used much until 1910 when Pickering decided that they had enough spectra to finish the Henry Draper catalogue and decided that it should use Cannon's system (Welther, 2005). This classification was officially adopted by the International Astronomical Union in 1922 (Darling).

Who else has made a similar contribution? Antonia Maury developed a method for classifying stars but her method "came too late: the Henry Draper system was already entrenched and her classes, though physically more significant, seemed unnecessarily elaborate" (Payne-Gaposchkin, 1984).

Again, Henrietta Leavitt's P-L relation for Cepheid variables has to rank up there. Jocelyn Bell's work on pulsars and Vera Rubin's study of dark matter is significant. Wendy Freedman's work using the Hubble telescope to nail down Hubble's constant is a major work.

## Criteria #4 – Citations By Others

In the interest of full disclosure, this idea is from my teacher Chris Fluke. He used the NASA ADS database to see which woman astronomer had a paper that was cited most often. The full results are in Appendix 4. But that kind of analysis is skewed toward the modern astronomer. Most astronomers that have ever lived are alive today (Hoskins). A modern astronomer is properly cited for recent work but Annie Cannon is not cited every time someone uses the Henry Draper Catalogue to identify a star (i.e. every time you see a star referred to by its HD number). And the stellar classifications are freely used without citing Cannon. But using this method we find the following astronomers meet this criterion: Wendy Freedman, Meg Urry, Margaret Burbidge, Vera Rubin, Jocelyn Bell and Penny Sackett.

## Criteria #5 – Awards Received

When an award is given in a field and that award is determined by others in that field, it serves as a clear signal of great work. Annie Cannon won the Henry Draper Medal in 1931. Harlow Shapley, a previous winner of this award said[2] "[Annie Jump Cannon is] "The benign presence of the Brick Building[the Harvard Observatory], noted collector of degrees [6 or so] and medals [at least a couple], author of nine immortal volumes [the Henry Draper Catalogue], and several thousand oatmeal cookies, Virginia reeler [this was probably Shapley transferring his hobby to Cannon], bridge player, and, especially, the recipient of the Draper Medal of the National Academy of Science - the first medal ever bestowed on a woman by the honorable body of fossils and one of the highest honors attainable by astronomers of any sex, race, religion, or political preference" (Women in Science Website).

Draper Award winners include: Martin Schwarzschild, Otto Struve, Vesto Slipher, Edward Pickering, S. Chandrasekhar, Lyman Spitzer, Penzias and Wilson, Butler and Marcy, and Harlow Shapley. It is given every 3-5 years on average (AAS Website).

The next year she won the Ellen Richards award. This award, given to women scientists, was disbanded after Annie Cannon won it because it was believed that woman in science had achieved parity. Annie didn't think so and she used her winnings from this award to start the Annie Cannon award (Powell, 1998).

Besides these awards, Annie Cannon was given a number of honorary degrees. This included degrees from the University of Delaware, Wellesley College, Oglethorpe University, Mt. Holyoke College, the University of Groningen and Oxford. She was also elected an honorary member of the Royal Astronomical Society (Brück, 1941). She was "one of the few women elected to membership in the American Philosophical Society (Powell).

In 1925, Annie Jump Cannon would receive an honorary degree from Oxford. She was the first woman so honored. She was the first woman to win the National Academy of Science's Draper Gold Medal in 1931 (Slaight, 2000) There would not be another woman getting this award until 1989 and that person shared it with her collaborator (NAS website, 2006). Note that the Draper gold medal is named after the same person as the Henry Draper catalogue that Annie Cannon worked on. She would also win the Ellen Richards award in 1932. In the following year, the Annie Cannon award was established.

Who else rates highly on this criterion? If a woman astronomer won the Nobel Prize, that would be a topper. Jocelyn Bell could have (and perhaps should have) won the Nobel when her associate Hewish won for work on pulsars (Hewish, 1974). Perhaps Henrietta Leavitt would have won the Nobel prize if she hadn't died so young (Papacosta, 2004).

There are other awards that might compare to the Draper medal. The Catherine Wolfe Bruce medal is awarded by the Astronomical Society of the Pacific. Female winners include Vera Rubin (2003),

[2] Words inside of brackets are added by the author.

Margaret Burbidge (1982), and Charlotte Moore Sitterly (1990). Other winners include: Bart Bok, Lyman Spitzer, Fred Hoyle, Otto Struve, Harlow Shapley, Edwin Hubble, Ejnar Hertzsprung, Arthur Eddington, William Huggins, Jacobus Kapteyn and Edward Pickering (ASP Website).

## Criteria #6 – Historical Acclaim

In Appendix 2, there are 5 lists of woman astronomers. There is a great deal of agreement between these lists. Any astronomer on any of these lists indicates significant contributions to astronomy and, probably, a certain amount of "popularity" as well. Annie Cannon is on all these lists. The following astronomers also made every list: Annie Jump Cannon, Cecilia Payne-Gaposchkin, Maria Mitchell, Caroline Herschel, Henrietta Leavitt. Note that 3 of these names are former computers (Cannon, Leavitt) or closely related (Payne). The other two predate the computers.

## Criteria #7 – Popularity

Remember, we only use this as a tie-breaker. If you can't determine a winner from all of the above, we humbly (perhaps even embarrassingly) offer this information. A series of Google searches were done in October of 2006. The searches were done in different ways and were done for each astronomer that seemed like significant competition in this paper's thesis. Cannon got the first or second greatest number of hits. Maria Mitchell did as well. Wendy Freedman and Caroline Herschel got a lot of hits but nowhere near as many as Cannon or Freedman. No one else got as many as half of the hits that these others received. Details are in Appendix 3.

## Commentary

"Classifying the stars has helped materially in all studies of the structure of the universe. No greater problem is presented to the human mind. Teaching man his relatively small sphere in the creation, it also encourages him by its lessons of the unity of Nature and shows him that his power of comprehension allies him with the great intelligence over-reaching all." – Annie Cannon (Women in Science Website)

Has this article thoroughly proven that Annie Jump Cannon is the most important woman astronomer of all time? No, but the criteria set forth here make a reasonable case.

1. Annie Cannon's work on the Henry Draper Catalogue is still used today. There are star catalogs that are larger and some that are more detailed (MAST GSC Catalogs Website). In this day of electronic computers, greater catalogs should be expected. But it is hard to think of more important catalogs that were created before the Information Age. Of the first 182 exoplanets that have been discovered, 148 of them are listed using the HD number of their host star (Butler, et.al, 2006). Of all other woman astronomers, only Henrietta Leavitt gets mentioned in this regard because of the large number of variable stars that she found. Caroline Herschel certainly participated in William Herschel's work.

2. There are several women who lead by example. Maria Mitchell holds a special place as the first American woman astronomer. The stories of Hypatia resound strongly today. Others may have

made more specific contributions to other astronomers. But there is no other award like the Annie Cannon award which she set up herself.

3. The stellar classification system that we use today was created by Annie Cannon. The discovery of the P-L relation of Cepheid variables is also very important. To find contributions equal to these two requires looking at more contemporary work: Rubin and dark matter, Porco and the Cassini findings, J. Bell and pulsars, and Freedman and the Hubble constant. It is very difficult to compare these breakthroughs made at different times but Cannon's work is still in constant usage.

4. Other astronomers are cited more often in professional journals than Annie Cannon. Once again, comparing astronomers of different eras is difficult. Still, this criteria has merit and is the most difficult to defend given this article's goal.

5. Looking at a list of awards given many years ago is very interesting. If the list was for movies, the names would create a story of how things changed in cinema over time. In the case of astronomy, the list shows what work was considered important. Annie's Draper medal win is no exception.

6. When looking at lists of women astronomers, it quickly becomes apparent that the list makers may have been looking over each other's shoulder. In fact, some lists were found to be identical and we didn't use them. Regardless, the names that always come up are very apparent. These lists will at least result in a short list of women who must be considered as the most important astronomer.

7. As a popularity contest, the Google search will substitute for a poll. Annie Cannon is very well known at least among astronomers.

## That's Just One Opinion, It Could be Wrong

Could an argument be made that some other woman astronomer should be considered the most important.

In the future, we may look at the work by Vera Rubin as the most important or Wendy Freedman's work might become the most famous. A female friend of mine made the point that if SETI finds extraterrestrial intelligence, Jill Tarter will be #1 among women astronomers. So simply adjust the claim of this article: the most important woman astronomer *based on what we know today*.

Caroline Herschel and other women were critical in the work of their brother's, father's or spouse's. So another adjustment to this article's claim: the most important woman astronomer based on what we know today *and not considering the work done by others that was enabled by these women*.

Hypatia might be considered the first martyr for astronomy. Just one more adjustment: the most important woman astronomer based on what we know today and not considering the work done by others that was enabled by these women *and not giving extra consideration for dying for the sake of knowledge*.

## Finally

Annie Jump Cannon is the most important woman astronomer in history. Cecilia Payne made very important contributions but not to the same extent as Annie Cannon. Maria Mitchell is very important just for being the first American woman astronomer but she did not have the opportunities to make the contributions of Annie Cannon. Caroline Herschel was a critical part of one of the most important families of astronomers but when we compare the timelessness of her contributions with Annie Cannon, we still consider Cannon the greater. Henrietta Leavitt, an equal to Cannon in terms of work and probably in terms of scientific importance, died early and did not have the same level of influence over the next generation as did Annie Cannon. Women astronomers living today can't be given the full respect that only time can provide.

## Last Word

The last word of this article ought not to come from a guy looking in from the outside. If someone else is considered the most important woman astronomer sometime in the future, a good candidate is Vera Rubin. Not only is her work on dark matter tremendously important, she is not shy about her philosophy:

"I live and work with three basic assumptions:

1. There is no problem in science that can be solved by a man that cannot be solved by a woman.

2. Worldwide, half of all brains are in women.

3. We all need permission to do science, but, for reasons that are deeply ingrained in history, this permission is more often given to men than to women." – Vera Rubin, (Weber)

# References

## A Note on the References

There were very few places where the references disagree and the disagreements seem minor. The number of stellar classifications in the original Pickering-Fleming system 14 (Merrill, 1941), 17 (Cannon, 1915) or 22 (Spekkens, 2003). The latter number might be confused with Antonia Maury's 22 general classifications (Cannon, 1915).

Special thanks to Leila Belkora for her comments and recommendations.

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## Appendix 1 – Annie Jump Cannon Biography Summary

| | |
|---|---|
| Dec. 11, 1863 | Born in Dover, Delaware |
| 1880 | Attends Wellesley College |
| Circa 1881 | Gets Scarlet Fever – results in partial deafness. |
| 1884 | Graduates from Wellesley |
| 1892 | Travels to Europe to photograph a solar eclipse |
| 1893 | Mother dies |
| 1893 | Gets a job at Wellesley. The school did not have a course in Astronomy when she attended but now it did. She gets interested in spectroscopy. |
| 1894 | Becomes a Wellesley student again eventually earning a master's degree in physics and astronomy. |
| 1895 | Transfers to Radcliffe Women's College which is next to Harvard University and has access to a better observatory. |
| 1896 | Starts working for Edward Pickering at the Harvard Observatory |
| 1897 | First article. Cowritten with Edward Pickering. |
| 1907 | Finally gets the master's degree from Wellesley that she started working on in 1894. |
| 1911 | Becomes curator of the Harvard Observatory |
| 1912 | First published article where a large number of stars are classified using Cannon's spectral categories (Cannon, 1912). |
| 1914 | Meets Harlow Shapley (Belkora, 2003) |
| 1916-1941 | Chairman of the Astronomical Fellowship Committee |
| 1918 | Publishes the first volume of the Henry Draper catalogue |
| 1921 | Get's doctor in astronomy degree from Groningen University – the first woman to do so. |
| 1922 | Goes to Peru to photograph stars not visible from the North. |
| 1923 | Voted one of America's 12 greatest women |
| 1924 | Finishes the Henry Draper Catalogue although extensions would be added later. |

| | |
|---|---|
| 1925 | Get's honorary degree from Oxford – first woman so honored. |
| 1931 | First woman to win the National Academy of Science's Draper Gold |
| 1932 | Awarded the Ellen Richards Prize |
| 1933 | Annie Cannon Award established |
| 1938 | Get's a permanent position at Harvard Observatory. |
| April 13, 1941 | Dies in Cambridge, MA from heart disease |
| 1949 | Henry Draper Catalogue Extension is published. Cannon is the co-author even though she died 8 years previously. |

## Appendix 2 – Lists of Women Astronomers

| ASP List[3] | Distinguished Women Website[4] | Marcy's List[5] | KidStuff Site[6] | Danielson[7] |
|---|---|---|---|---|
| Sallie Baliunas | En Heduanna | Caroline Herschel | Sophia Brahe | Aphra Behn |
| Jocelyn Bell Burnell | Aganice | Maria Mitchell | Margaret Burbidge | Annie Jump Cannon |
| Ann Boesgaard | Aglaonike | Annie J. Cannon | Annie J. Cannon | Agnes Mary Clerke |
| Nancy Boggess | Hypatia | Henrietta S. Leavitt | Deborah Crocker | Kitty Ferguson |
| Margaret Burbidge | Sophia Brahe | Cecilia Payne-Gaposchkin | Marie Cunitz | Caroline Herschel |
| Annie Cannon | Marie Cunitz | Beatrice M. Tinsley | Jeanne Dumee | Henrietta Swan Leavitt |
| Agnes Clerke | Marie Magrarethe Winkelmann Kirch | Jocelyn Bell Burnell | En Heduanna | Maria Mitchell |
| Sandra Faber | Nichole-Reine Lepaute | Nancy Boggess | Williamina Fleming | Cecilia Payne-Gaposchkin |
| Debra Fischer | Caroline Herschel | E. Margaret | Cecelia Payne- | Vera Rubin |

[3] http://www.astrosociety.org/education/resources/womenast_bib.html

[4] http://www.distinguishedwomen.com/subject/astrono.html

[5] http://astro.berkeley.edu/~gmarcy/women/history.html

[6] http://www.kidscosmos.org/kid-stuff/women-astro.html

[7] Danielson, D.R., 2000, The Book of the Cosmos, Perseus Publishing, p. 556, see index listing for women's contribution to cosmology

| | | | | |
|---|---|---|---|---|
| | | Burbidge | Gaposchkin | |
| Williamina Fleming | Mary Fairfax Somerville | France Cordova | Caroline Herschel | Mary Somerville |
| Wendy Freedman | Caterina Scarpellini | Sandra Faber | Sethanne Howard | |
| Caroline Furness | Maria Mitchell | Margaret Geller | Margaret Murray Huggins | |
| Margaret Geller | Sarah Frances Whiting | Margherita Hack | Maria Mergarethe Kirch | |
| Heidi Hammel | Margaret Lindsey Murray Huggins | Eleanor Helin | Nichole-Reine Lepaute | |
| Caroline Herschel | Williamina Paton Stevens Fleming | Roberta Humphreys | Henrietta Swan Leavitt | |
| Dorrit Hoffleit | Annie Jump Cannon | Christine Jones | Maria Mitchell | |
| Helen Hogg | Henrietta Swan Leavitt | Catherine Pilachowski | Louise Pierry | |
| Margaret Huggins | Charlotte Emma Moore Sitterly | Mercedes Richards | Sabliere | |
| Dorothea Klumpke-Roberts | Emma Bakes | Sally Ride | Mary Somerville | |
| Henrietta Leavitt | Bonnie Buratti | Nancy Roman | Sonduk | |
| Jane Luu | Eleanor Margaret Peachey Burbidge | Vera Rubin | Janet Taylor | |
| Antonia Maury | Jocelyn Bell Burnell | Carolyn Shoemaker | Sarah Whiting | |
| Maria Mitchell | Eleanor Francis Helin | Jill Tarter | | |
| Cecilia Payne | Helen Sawyer Hogg | Jacqueline Van | | |

| | | | | |
|---|---|---|---|---|
| Gaposchkin | | Gorkom | | |
| Catherine Pilachowski | Tamara E. Jernigan | Sidney Wolff | | |
| Sally Ride | Rosaly M.C. Lopes-Gautier | | | |
| Nancy Roman | Cecilia Payne-Gaposchkin | | | |
| Vera Rubin | Nancy Roman | | | |
| Anneila Sargent | Carolyn Shoemaker | | | |
| Carolyn Shoemaker | | | | |
| Charlotte Sitterly | | | | |
| Mary Somerville | | | | |
| Jill Tarter | | | | |
| Beatrice Tinsley | | | | |
| Virginia Trimble | | | | |
| Sidney Wolff | | | | |
| | | | | |

## Mentioned in all lists: Annie Jump Cannon, Cecilia Payne-Gaposchkin, Maria Mitchell, Caroline Herschel, Henrietta Leavitt.

## Appendix 3 – Google Counts

Google Counts as of October 24, 2006. Two different methods were used to see how many hits Google found for various woman astronomers. One method just used the first and last name of the astronomer along with the word astronomer. However, these counts were very high so a second method did the same thing but added a plus sign in front of each word in the search phrase to force all hits to have all three words. The results are shown below.

| Google Search Phrase | Count 10/24/2006 | Google Search Phrase | Count 10/28/06 |
|---|---|---|---|
| annie cannon astronomer | 530,000 | +annie +cannon[8] +astronomer | 51,500 |
| maria mitchell astronomer | 442,000 | +maria +mitchell +astronomer | 61,600 |
| wendy freedman[9] astronomer | 174,000 | +wendy +freedman +astronomer | 19,800 |
| hypatia astronomer | 88,100 | +hypatia +astronomer[10] | 21,200 |
| caroline herschel astronomer | 58,900 | +caroline +herschel +astronomer | 32,500 |
| vera rubin astronomer | 58,100 | +vera +rubin +astronomer | 21,400 |
| cecilia payne astronomer | 54,400 | +cecilia[11] +payne +astronomer | 20,300 |
| sarah whiting astronomer | 53,100 | +sarah +whiting +astronomer | 23,600 |

[8] Why would Annie Cannon get a lower count this way? Perhaps the first search found other astronomers named Cannon.

[9] Undoubtedly, Wendy Freedman's counts could be higher because her last name is often spelled without the "d". However, searches that allow for "Freeman" include hits for Freeman Dyson.

[10] Using only one word names makes this comparison unfair.

[11] First name is sometimes spelled "Cecelia" but that doesn't affect the counts much.

| | | | |
|---|---|---|---|
| henrietta leavitt astronomer | 34,300 | +henrietta +leavitt +astronomer | 16,900 |
| jill tarter astronomer | 33,700 | +jill +tarter +astronomer | 13,400 |
| meg urry astronomer | 25,200 | +meg +urry +astronomer | 475 |
| penny sackett astronomer | 24,500 | +penny +sackett +astronomer | 521 |
| margaret Burbidge astronomer | 437 | +margaret +Burbidge +astronomer | 218 |

## Appendix 4 – E-Mail from Chris Fluke

Forum: HET607 Weeks 11 and 12

Date: Mon Oct 23 2006 08:58

Author: Fluke, Chris <cfluke@astro.swin.edu.au>

Subject: Re: Most Important Woman Astronomer

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Hi all,

When making any judgements of "Most Important", we really do need to define our criteria. Are they the most well-known, and therefore have an opportunity to be seen as a positive role model or potentially act as a mentor? Or do we try and find an objective metric which can be used to judge their impact on astronomy? I thought I would try the latter, and use ADS to get some information on citation counts - this is one of the most popular measures of a researcher's impact. If you write papers and nobody ever cites them, did they contribute? [I hope so, because I've got a few low citation papers....]

I'm going to "rank" these women (plus some others) on the basis of their citations. All of these women have published papers since the 1950s.

A. Most citations to a single paper on which they were first author:

1. Wendy Freedman 979 (Final results of HST key project on H0)

2. Meg Urry 854 (A paper on the unified model for radio loud AGN)

3. E.Margaret Burbidge 754 (The famous B^2FH paper on the synthesis of elements in stars)

4. Vera Rubin 453 (Rotation velocities of galaxies - leading to "discovery" of dark matter)

5. Penny Sackett 120 (current director of Mount Stromlo Obs)

P39 - The Most Important Woman Astronomer – by Paul Kohlmiller

As a first author, Jocelyn Bell (Burnell) is a long way off the pace, and her top-cited paper is the pulsar discovery paper by Hewish & Bell with 170 citations. Carolyn Porco is also a long way off (best is 39 citations).

Number of papers with more than 50 citations (this does bias against women who have published recently, as there has been less time to earn big citation counts)

1. E. Margaret Burbidge 21

2. Wendy Freedman 20

3. Vera Rubin 17

4. Meg Urry 9

5. Penny Sackett 4

Who else can you find that should move higher into this list?

Chris