Illinois—Where Astronomical Photometry Grew Up

Barry B. Beaman
6804 Alvina Road, Rockford, IL 61101; praesepe44@aol.com

Michael T. Svec
Furman University, Department of Education, 3300 Poinsett Highway, Greenville SC 29613; Internet: michael.svec@furman.edu

Presented at the 100th Annual Meeting of the AAVSO, October 7, 2011; received January 21, 2012; revised February 2, 2012; accepted February 6, 2012

Abstract In 1903 Dr. Joel Stebbins joined the University of Illinois faculty as an astronomy instructor and Director of the University of Illinois Observatory. In 1905 he and F. C. Brown began experimenting with selenium sell photometry and developed the equipment and many of the photometric practices used then. Those practices formed the foundation on which present day photometry processes are based. This paper will trace the history of Stebbins' career and his development of photoelectric photometry from 1903 to 1922. This story explains how Stebbins' wife, May, caused a change in astronomical observing that continues today.

1. Introduction

The prairies of central Illinois may seem an unlikely place to begin a photometric revolution. Illinois is a flat land state with only about 100 clear nights per year, the average elevation is only 600 feet above sea level, and the highest point is only at 1,500 feet. Yet, Illinois has produced its share of prominent and innovative astronomers. George Ellery Hale built his Kenwood Observatory in the heart of Chicago. Edwin Hubble spent his teen years in the Chicago suburbs and was educated at University of Chicago. Grote Reber built the World's first parabolic-steerable radio telescope. It was thirty feet in diameter and located in Reber's backyard in Wheaton. Rumor has it that Wheaton still has a city ordinance limiting the size of antennas residents can construct at their homes. And then there was Joel Stebbins.

Chicago was not the only cradle of astronomical innovation, there was also Urbana, home to the University of Illinois Observatory. Built in 1896 as a teaching facility, the Observatory was typical of late 19th century facilities with its Warner and Swasey/Brashear refractor, pendulum clocks, transit telescopes, and focus on visual observations. It stands in contrast to modern observatories in which star light typically falls upon some type of electronic detector. Trace the linage of these electronic devices back through the decades and you arrive at the doorstep of the University of Illinois Observatory where you will meet

Dr. Joel Stebbins, who "[r]aised on the astronomy of the 19th century, he lived to witness much of the new astronomy of the 20th-which he helped create" (Svec 1992). Stebbins arrived in 1903 as the new observatory director. While the skies may not be as dark and clear as the western mountain top observatories, the UI Observatory did have ready access to the campus. Astronomy was a division in the Mathematics Department and Stebbins had teaching responsibilities in both math and astronomy. Stebbins was able to develop and improve new photometric instruments and pursue an astronomical research program because of willingness and ability to collaborate with the Illinois physicists.

2. The story

Joel Stebbins was born in Omaha, Nebraska, on July 30,1878, and educated in the Omaha Public Schools. His interest in Astronomy started from an elementary school class. He built his first telescope by attaching lenses to a tube made from rolled up newspapers. Stebbins' advanced education was at the University of Nebraska where he received a Bachelor of Science degree. Graduate study started at the University of Nebraska, continued at the University of Wisconsin, and concluded at the University of California at Lick Observatory and on the Berkeley campus. Stebbins received the third Ph.D. in Astronomy granted by the University of California, in May of 1903 (Whitford 1978).

Stebbins' first employment after receiving his Ph.D. was as the Astronomy Instructor at the University of Illinois in Urbana. Along with the instructor position he was assigned the Directorship of the UI Observatory (Figure 1). While the Observatory was a relatively new facility in good condition and well equipped with a 12-inch Brashear refractor and a polarizing photometer, it had no operating budget! The Observatory's first year budget ended up being $7.00 and it came out of Stebbins' pocket! But, life does get better. In 1905 he received a budget of $750.00 from the University Trustees.

Stebbins first major project at UI was a survey of 107 double stars to determine their brightness using the Observatory's 12-inch Brashear telescope and a Pickering Polarizing Photometer made by Alvan Clark and Sons. This project was ongoing when a good thing happened. On June 27, 1905, Stebbins married his college sweetheart, May Louise Prentiss, also of Omaha. Then, in August, they travelled with Lick Observatory astronomer Heber Curtis and his wife, Mary, to study the 1905 Solar Eclipse in Labrador.

Upon returning to Urbana, Stebbins resumed his photometry program; but life at the Observatory was about to change, and the way astronomy research was conducted was about to change forever! In Stebbins' own words:

> The photometric program went along well enough for a couple of years until we got a bride in our household, and then things began to happen. Not enjoying the long evenings alone, she found that if

> she came to the observatory and acted as a recorder, she could get me home earlier. She wrote down the numbers as the observer called them, but after some nights of recording a hundred readings to get just one magnitude, she said it was pretty slow business. I responded that someday we would do all this by electricity. That was a fatal remark. Thereafter she would often prod me with the question: "When are you going to change to electricity?" (Stebbins 1957)

In the following summer Stebbins attended a Physics Department demonstration where he met a young instructor, Fay C. Brown. Brown was demonstrating a selenium cell that, when illuminated by a lamp, would ring a bell. Stebbins had an idea: "why not turn on a star to a cell on the telescope and measure a current?" On 23 June 1907, after some improvements, Stebbins and Brown began the project to measure the variation of the Moon's light with phase:

> I soon made friends with Brown, and in due time we had a selenium cell on the 12-inch refractor; I operated the telescope and a shutter while Brown looked after the battery, galvanometer, and scale. The first trial was on Jupiter-no response; several more trials, still no response. I said to myself, "I'll fix him." The moon was shining through a window; I took the cell with attached wires off the telescope and exposed it to the moon. The galvanometer deflection was measurable with plenty to spare. Result: We spent a couple of months measuring the variation of the moon's light with phase. Our resulting light curve turned out to be the first since the time of Zollner in the 1860s. (Stebbins 1957; see Figure 2)

The involved process for the Moon project would begin with Stebbins, at a window in the observatory classroom, making a set of four ten-second exposures by pointing the cell at the Moon. One minute was allowed between each exposure for the cell to recover. Brown, at the galvanometer in the West Central Transit room, recorded the deflection and the time for each exposure. After each set the photometer was calibrated at various distances from a standard Kohl candle. A second set of lunar observations would follow the calibration. The author suspects that calibration was done at the beginning and end of the process (Figure 3).

This was not the World's first attempt at photoelectric photometry. In 1892 selenium cells made by G. M. Minchin of Dublin were used by a Professor Fitzgerald and W. H. S. Monck, an amateur astronomer who owned a 9-inch refractor that they used to detect Jupiter, Venus, and Mars. In 1895 Minchin joined with Mr. W. E. Wilson to measure some stars with Wilson's 24-inch reflector. Two short papers were published by Minchin and his associates in 1895 and 1896. In Germany E. Ruhmer used his homemade cells to observe a solar eclipse on October 31, 1902, and a lunar eclipse on April 11–12, 1903. These are the only known successful applications of selenium cells prior to Joel Stebbins' work. Stebbins (1940) wrote that he learned of Minchin and others while preparing the literature review for the paper on the phases of the moon. Hearnshaw (1996) noted: "It is doubtful that the experiments made by Minchin had much influence on the future course of stellar photometry."

Brown left Illinois for a fellowship at Princeton at the end of the summer of 1907 yet returned to Urbana to work with Stebbins during the following two summers to improve the photometer. Progress was both deliberate and occasionally serendipitous. A dropped and broken selenium cell led to the discovery that smaller cells produced a signal with the same strength but less noise. A clear, sub-zero night provided evidence that cold sensors produce less noise.

Continued improvements to the selenium cell allowed Stebbins to detect third magnitude stars. This allowed the collection of sufficient data to publish a light curve for β Persei (Algol; Figure 4). Here is Stebbins' (1940) account of the first efforts toward continuing studies of stars with photoelectric photometry:

> After many experiments we learned that the irregularities of a selenium cell were much reduced if the cell was kept at a uniformly low temperature in an ice pack, but even so there were only a few bright stars within reach of the apparatus. We began with the comparison of Betelgeuse and Aldebaran with the assumption that any changes in the relative magnitude would be due to Betelgeuse. Finally a new cell from Giltay gave about a three-fold improvement over previous cells, and we were able to take up a detailed study of Algol, which is about second magnitude.
>
> One observing season of six months was devoted almost entirely to this star, and it was possible to detect for the first time the secondary minimum of Algol, and the continuous variation between eclipses. Following this study, we tested a number of bright spectroscopic binaries for small variations in light. As luck would have it, the first two stars so tested turned out to be eclipsing binaries, Beta Aurigae, period 4 days with two equal minima of about 0.08 mag. each, and Delta Orionis, period 5.7 days, with minima of 0.08 and 0.05 mag. spaced in agreement with the eccentric orbit. Of the other stars tested Alpha Coronae Borealis also gave unmistakable evidence of an eclipse, which was confirmed later with the photoelectric cell. (Stebbins 1940)

After completion of the Algol observations in 1909, the photometry process was sufficiently developed for use as a research tool. A much higher level of observational accuracy had been achieved and allowed Stebbins the opportunity to study eclipsing variables for the direct determination of the diameter, mass, and density of stars. Stebbins concluded that there must be many spectroscopic binaries with eclipses of small range that could not be discovered using older photometric processes. He made a list the most favorable cases. The previously mentioned first two bright stars tested—β Aur and δ Ori—showed eclipses at the predicted times of about ten percent of the light at constant phase. A systematic campaign at Urbana over the following years turned up many more. As an example of this campaign, during March 1911, photometric observations were made of β Aur, α Gem, ξ UMa, δ Ori, α Ori, and α UMi, and by the following March, ι Ori, α Vir, and β Sco joined the observing program. Although productive, the selenium photometer was a challenge to operate.

3. Enter the photoelectric cell

Swiss born and educated physicist Jakob Kunz arrived in Urbana in 1909 and began a research program focusing on photoelectric cells. In 1911, Kunz and fellow Illinois physicist W. F. Schulz met Stebbins and suggested he might consider replacing the selenium cell with a photoelectric cell. One of Kunz's graduate students, J. G. Kemp, completed a dissertation in 1912. Kemp found that a potassium-hydrogen cell was about 200 times the sensitivity of the selenium cell and noted that "A design has been made for a sensitive photo-electric cell for photometric work in astronomy. It is expected to get a cell which will be sensitive enough to use instead of the erratic selenium cell now used." (Kemp 1913). It is interesting that this change replaced a solid state device (selenium cell) with a glass tube device containing special coatings and small amounts of hydrogen or other suitable gases. The potassium-hydrogen cell is a specific version of the alkali-cathode cell.

Stebbins continued with the selenium photometer up to his departure in the fall of 1912 for a sabbatical in Europe. Kunz and Schulz first observed α Aur with a photoelectric photometer in December of 1912 and then α Boo the following April. While in Europe on sabbatical in August 1913, Stebbins met Hans Rosenberg of Tübingen who was successfully using an alkali-cathode photometer. Campbell (1913) recounts:

> By way of comment on Rosenberg's paper, Stebbins went to the blackboard and wrote down the following table, contrasting the work of Meyer and Rosenberg's electric-cell photometer and his own selenium photometer...

Photometer	Telescope	Star of	Time to make observation	probable error of one determination
Electric-cell	5-inch	5th mag	2 min	+ 0.003 mag
Selenium	12-inch	2nd mag	60min	+ 0.01 mag

After returning from sabbatical, Stebbins and Kunz concentrated on developing the new photometer incorporating a photoelectric cell and Wulf string electrometer. The selenium photometer was never used again for published research. In the summer of 1915 the photometer had progressed to the point that Stebbins used it on the 12-inch refractor at Lick Observatory (Figure 5) to obtain a light curve of β Lyr.

Back in Urbana he began an aggressive research program which resulted in a series of papers in the *Astrophysical Journal* on eclipsing binaries λ Tau, σ Aql, β Per, AR Cas, ellipsoidal variables π^5 Ori and b Per, and Nova Aql No. 3 (1918). Stebbins and Kunz also travelled to Wyoming to study the solar eclipse. Public open houses were suspended in 1918 due to navigation classes supporting the war effort and time needed to reduce data from the Nova and eclipse expedition. Dr. Elmer Dershem joined the Observatory staff in 1917 and rebuilt the photometer in the summer of 1919. Dershem would leave for Berkeley and help Edith Cummings at Lick Observatory build their photometer in 1920. By 1922, Charles Clayton Wylie completed the first Illinois astronomy doctorate for his photoelectric studies of the Cepheid η Aql, and σ Aql, noting its variations due to tidal distortions.

In 1922 Stebbins moved to the University of Wisconsin to become Director of the Washburn Observatory. He completed work on an impressive number of eclipsing binaries over a period of several years. From 1925 onward, he moved to other fields of astronomical photometry and spent many summers at Mt. Wilson as a research associate. Although he was in Madison, he took with him C. M. Huffer, an Illinois mathematics graduate, who went on to become a photoelectric pioneer in his own right recording thousands of observations of eclipsing, late type, and red variables as well as galaxy magnitudes for Edwin Hubble. From the early 1930s Huffer was Stebbins' main collaborator on the photometric study of interstellar reddening. Stebbins also maintained a professional and personal relationship with Kunz who continued to provide Stebbins and the rest of the astronomical community with photoelectric cells until Kunz's death in 1938. Of the thirteen American observatories identified by Hearnshaw as conducting photoelectric research before World War II, six used Kunz photocells (Urbana, Washburn, Lick, Yerkes, Mt. Wilson, and Harvard).

4. Postscript

The Observatory continues to be a teaching facility. In recognition of the significance of the development of photoelectric photometry, the Observatory was declared a National Historic Landmark by the U.S. Department of the Interior. Deferred maintenance, harsh winters, and age have taken their toll on the University of Illinois Observatory. In conjunction with the Astronomy Department, a Friends of the University of Illinois Observatory group has formed in hopes of restoring and preserving the historic structure. For more information visit: https://www.facebook.com/U.of.lllinois.Observatory and http://www.astro.uiuc.edu/friends/fuio/

5. Conclusion

Stebbins (Figure 6) did not see central Illinois as a limitation to astronomical research. He commented "One doesn't have to go to a place where there is a large observatory to find something to do. I have found conditions here in Urbana more favorable to my work than anywhere else. At large observatories there is always something the matter" (Anon. 1916). Joel Stebbins continued to use, create, and improve photoelectric equipment and processes for the rest of his life. His last paper, written with his former student, Dr. Gerald Kron, dealt with the standardization of the six-color system in terms of black-body temperature. It was published in 1964 just two years before Stebbins died. While not the first to use photoelectric photometry, Joel Stebbins deserves the credit for developing and proving, with many papers based on countless hours of observations and many equipment and process improvements, photoelectric photometry to be the tremendous scientific tool that it has become. The key to the astronomer's success was the collaboration with physicists. Stebbins' research was motivated by astrophysics and his papers reflect that emphasis with data and analysis. It was the collaboration with F. C. Brown and then Jakob Kunz who solved the technical instrument problems that enabled the instrument to gather the data presented by Stebbins, proving the value of the photoelectric photometer. And it all started out on the Illinois prairie in a little town named "Urbana" because May had writer's cramp!

References

Anon. 1916, "Professor Stebbins tell how to measure starlight," *Daily lllini* (24 November), 1.

Campbell, W. W. 1913, *Publ. Astron. Soc. Pacific*, **25**, 275.

Hearnshaw, J. B. 1996, *The Measurement of Starlight: Two Centuries of Astronomical Photometry*, Cambridge, Univ. Press, Cambridge.

Kemp, J. G. 1913, *Phys. Rev.*, **1**, 274.

Stebbins, J. 1910, *Astrophys. J.,* **32**,185.

Stebbins, J. 1940, *Publ. Astron. Soc. Pacific*, **52**, 235.

Stebbins, J. 1957, *Publ. Astron. Soc. Pacific*, **69**, 506.

Svec, M. T. 1992, *Sky & Telescope*, **83**, 496.

Whitford, A. E., 1978, *Biographical Mem.*, **49**, 1, Natl. Acad. Sci., Washington, D.C.

Figure 1. The University of Illinois Observatory in 1905 when Dr. Stebbins was starting to think about using electricity. From the collection of M. Svec.

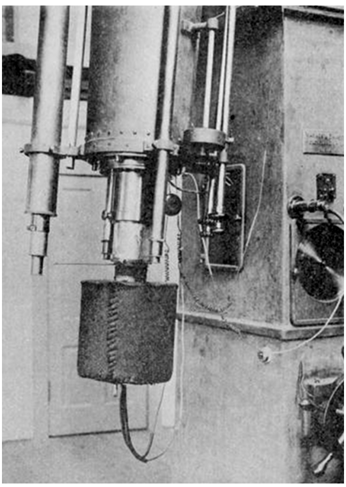

Figure 2. The University of Illinois Observatory selenium cell photometer about 1910. The cell is in an ice pack attached to the 12-inch refractor. From Stebbins (1910).

Figure 3. Page (top) from Stebbins notebook titled “Selenium 1907 Febr. 15 to 1908 January 25.” The note states that F. C. Brown was at the galvanometer in the transit room and Joel Stebbins was in the classroom exposing the selenium cell (bottom) to the Moon. Provided by M. Svec, courtesy of University of Wisconsin Archives.

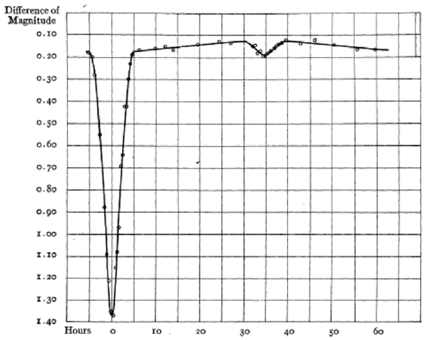

Figure 4. Classic Light curve of β Per showing two new features: the secondary eclipse and the reflection effect. From Stebbins (1910).

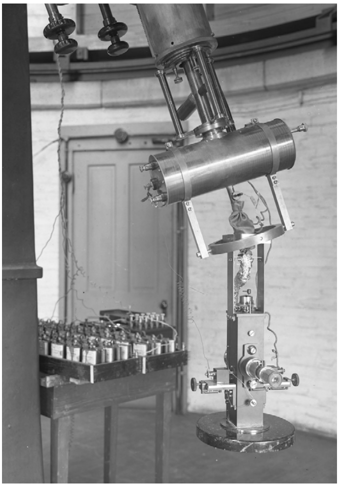

Figure 5. The photometer Stebbins used from about 1915 at the UI Observatory. The photometer contains a Kunz rubidium cell with a direct connection to a string electrometer specifically built for Stebbins by William Gaertner and Company of Chicago. The other parts were constructed by Mr. J. B. Hayes, mechanician of the Illinois physics department. The telescope is the UI 12-inch Brashear refractor. Provided by M. Svec, courtesy of University of Illinois Archives.

Figure 6. Dr. Joel Stebbins at Washburn Observatory, University of Wisconsin, about 1924. The telescope is a 15.3-inch Clark refractor. The photometer is possibly an early gimbal-mounted string electrometer.

The Man with the measuring tool! All because May had writer's cramp!

Provided by M. Svec, courtesy of University of Wisconsin Archives.