The Visual Era of the AAVSO Eclipsing Binary Program

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Abstract The beginning of eclipsing binary minima timings by visual observers in North America is described, and the history of the AAVSO's Eclipsing Binary Committee during the era of visual observation is outlined, with particular attention to the observational programs, the production of charts and ephemerides, and the reduction and publication of the minima timings. During the period 1965–2005, AAVSO observers timed more than 17,000 minima, determined periods and light-curve types for neglected and newly discovered eclipsing binaries, and improved the light elements and corrected erroneous periods for many more.

1. Introduction

If Harvard College Observatory Director E. C. Pickering was the godfather of the AAVSO, Dr. Joseph Ashbrook, editor of *Sky & Telescope*, fulfilled that role for the AAVSO's eclipsing binary program. Before 1960, pioneer amateur photoelectric observers such as John Ruiz and Donald Engelkemeier timed a few minima of bright eclipsing binaries, but no visual observers in North America were timing minima. Indeed, visual observers were unaware that they could make a useful contribution in this field.

Pickering himself suggested adding Algol-type eclipsing variables to the AAVSO program as early as 1913, but William Tyler Olcott didn't think the more intensive observing required for such stars would appeal to observers, and AAVSO remained focused on the more leisurely long period variables. In 1951, AAVSO Recorder (Director) Margaret Mayall consulted with Ashbrook (Figure 1), then at Yale University, about the possibility of visual observers timing the minima of eclipsing binaries. Ashbrook had a longstanding interest in the subject, having observed β Lyr as far back as the 1930s. Ashbrook drafted a memorandum on how to observe these stars and noted that minima timings were "of sufficient importance to warrant such a program" (Williams and Saladyga 2011).

Nothing further was accomplished at that time, but in 1957 AAVSO member Jeremy Knowles authored an Observer's Page article in *Sky & Telescope*, "Another Look at Algol" (Knowles 1957). He noted that the period of Algol is variable and described the tracing paper method for determining an eclipsing binary's time of mid-eclipse. He also declared, "There is a broad field open to amateurs in the timing of minima of eclipsing variables." Visual estimates of an Algol minimum made by Ashbrook were used for illustration. Ashbrook now served on the magazine's editorial staff and was surely responsible for selecting this article for publication.

Ashbrook made a first attempt at stimulating visual minima timings with an Observer's Page article on U CrB in the April 1959 *Sky & Telescope*, including a chart, comparison sequence, and predictions of future minima (Ashbrook 1959). But U CrB is a difficult star with a long, slow minimum requiring a night-long vigil, and apparently no readers responded to this appeal.

In June 1960, astronomer Alan H. Batten authored a feature article in *Sky & Telescope*, "Why Observe Stellar Eclipses?" in which he noted the professional astronomer's need for EB observations (Batten 1960). In the same issue, Ashbrook tried again and published a Celestial Calendar article about the eclipsing binary SZ Her with a chart and minima predictions (Ashbrook 1960). A few months later he published a similar article on RZ Cas. Both of these stars have rapid, deep minima and can be observed effectively in only two or three hours. This time several readers responded. Ashbrook reduced the observations and published the resulting times of minima in later issues. The era of visual timings of EB minima had begun.

Over the next few years, Ashbrook introduced additional eclipsing binaries, such as X Tri, XZ And, and Y Leo, good targets for visual observation and known to exhibit period variations. By 1964, several observers were regularly reporting minima timings to *Sky & Telescope* and represented a growing community of interest.

The birth of the AAVSO Eclipsing Binary Committee had some parallels with the birth of the AAVSO. In 1912, William Tyler Olcott became section leader for variable stars in the new Society for Practical Astronomy (SPA) at the same time he was organizing the AAVSO. When Olcott resigned from his SPA position to devote himself to the AAVSO, most of the other section members followed him. In 1965, Illinois college student David B. Williams took the first steps to organize amateur eclipsing binary observers as part of a proposed National Association of Stellar Observers. This activity seems to have attracted the AAVSO's notice, because he soon received a letter from AAVSO Director Margaret Mayall, inviting him to chair an AAVSO Eclipsing Binary Committee. He and most of the other EB observers were already AAVSO members, so he immediately accepted.

Ashbrook, who was also named to the committee, prepared instructions for observers and, calling upon his vast knowledge of the literature, compiled a list of ninety-eight EBs that were suitable for visual observation and were known to have variable periods or other features of interest. Ashbrook's list became the "official program" and, with Williams providing predicted times of minima and charts, the AAVSO Eclipsing Binary Committee was off and running.

Williams (Figure 2) continued as chairman until 1969, when he was succeeded by the program's most active observer at the time, Marvin E. Baldwin, who continued to lead the EB Committee for almost forty years. Baldwin was succeeded in 2007 by Gerard Samolyk, who had served effectively as Baldwin's deputy on the committee for many years (Figure 3).

2. Observations

Unlike most of the variables in the traditional AAVSO program, for which a single estimate of brightness could be made at any time, an eclipsing binary required estimates made every 10 or 15 minutes, covering both the descending and ascending branches of the light curve, to determine the time of mid-eclipse. This meant a commitment of two to four hours (and sometimes more), depending on the rapidity of the light changes, so that at least 0.5 magnitude of variation was observed.

At first, the AAVSO EB program operated conventionally, with most observers timing minima of the recommended stars. But for some, this short list didn't satisfy their observing appetites. Baldwin was the first to start investigating non-program stars, identifying likely candidates in the catalogs, calculating predictions from the published light elements, and then trying to catch a minimum. His discovery that the eclipses of V342 Aql were arriving 2.5 hours early led to publication of a report in the *Information Bulletin on Variable Stars* (*IBVS*; Baldwin and Robinson 1965), the first of many papers to appear in *IBVS*, *JAAVSO*, and the weightier professional journals, all emanating from the AAVSO EB program and its growing corps of enthusiastic observers.

Within a few years, there were enough accumulated minima timings to begin tracking period variations. The first papers based on AAVSO visual timings reported improved light elements for sixteen stars that had drifted from their predicted times of minima (Baldwin 1973, 1974).

By the mid-1970s, the program usually involved fifteen to twenty active observers, who were reporting from 300–500 minima timings each year. The earlier solo efforts to investigate neglected EBs also evolved into several team efforts. The Puppis Project targeted more than a dozen EBs with unknown periods or types in that constellation. Observers were invited to monitor these stars on a continuous basis until enough minima were found to reveal the period and plot a complete phased light curve. One target of this project, MP Pup, was found to have the remarkably inconvenient period of 0.999 day (Baldwin *et al.*, 1994).

One very important but brief campaign involved θ^1 Orionis A in the Trapezium, a newly discovered EB with an announced period of 195 days.

Baldwin monitored this star and found it faint at a time that suggested the period might be only one-third of the published value. The next minimum based on this shorter period was predicted for August 23, 1976, and AAVSO observers were asked to examine θ^1 Orionis A low in the east at dawn. Two observers were favored with clear skies and horizons and found the star faint, confirming the shorter period (Baldwin 1977).

The Southern Project, to begin observing some of the sorely neglected EBs at far southern declinations, was launched in 1978. Jan Hers in South Africa prepared some charts, but this project never gained real momentum due to lack of dedicated southern observers. Finally, in 1994 Samolyk took direct action and, taking a portable telescope to Bolivia during a solar eclipse expedition, he timed half a dozen minima of far southern stars.

Newly discovered EBs provided many additional opportunities for cooperative observing campaigns. When nova hunter Dan Kaiser noticed the deep eclipse of the suspected variable NSV 3005 (now OW Gem) on his search photos, he alerted chairman Baldwin and the remainder of the 16-day minimum was documented (Kaiser *et al.* 1988). An examination of the Harvard patrol plates revealed the 1,259-day period (Kaiser 1988). Williams (1989) used photoelectric photometry to find the shallow, highly displaced secondary minimum. A successful campaign was organized to record the next observable primary eclipse (Hager 1996, Kaiser *et al.* 2002), and eventually AAVSO CCD observers provided a light curve that, combined with radial velocities, allowed professional investigators to determine the radii and masses of the component stars and the unusual evolutionary status of this remarkable binary system (Terrell *et al.* 2003).

Over the next several years, Kaiser continued to discover new EB stars brighter than tenth magnitude, and he was soon joined (and put out of business) by the ROTSE and Hipparcos satellites, which found dozens more, several with minima deep enough to be timed by careful visual observers. All these new discoveries led to the development of a conveyor-belt process of investigation: the visual observers monitored each star until the period could be determined, then the CCD observers compiled a complete light curve, and finally the professionals added radial velocities and performed the combined analysis, resulting in publication.

3. Charts

The first charts for eclipsing binaries with comparison star magnitudes were presented in *Sky & Telescope* in the articles introducing each star—small fields encompassing only the variable and its comparison sequence. AAVSO observers were accustomed to charts of various scales to assist in finding as well as observing variables. So in 1965, chairman Williams began drafting and distributing charts that showed each field on a broader scale, similar to the “a” scale charts with which AAVSO observers were familiar, with an inset box identifying the variable and its comparison sequence.

A few new stars were added to the chart list using the resources then available. Some EBs were already identified on existing AAVSO charts—RT And, for example, with a good comparison sequence for nearby RZ And. V346 Aql and SS Lib were also plotted on existing AAVSO charts for other variables. Z Dra was located and charted using the Franklin-Adams photographic atlas accessed at a professional observatory. To provide visual comparison star sequences for these stars, Williams used the classical “step” method to estimate the brightness differences of selected comparison stars; then the variable’s published visual magnitudes at maximum and minimum provided two calibration points on the step scale that could be used to convert the step values to magnitudes.

Baldwin began to identify many additional EBs and create his own sketch charts by using published light elements to calculate times of minima, then monitoring the stars nearest the variable’s position until one of them dimmed into eclipse. Having identified the variable, he then chose suitable comparison stars differing by approximately 0.5 magnitude and assigned them arbitrary values of 10, 20, 30, and so forth. This “modified” step method was rough but adequate for timing minima, since the only requirement was that the light curve be symmetrical.

When observer David Florkowski enrolled in the astronomy program at the University of Florida, a center for EB research, he was able to exploit the library and find identification charts for many EBs. Finally, with the advent of the Vehrenberg photographic *Atlas Stellarum*, the persistent chart problem could be solved in a comprehensive manner. Ed Halbach and his team at the Milwaukee Astronomical Society made enlargements of EB fields from the Vehrenberg atlas and produced 380 charts in AAVSO format (mostly “d” scale). Gary Wedemayer performed extensive library research at the University of Wisconsin-Madison to identify many EBs for this project. These charts served the program well for a quarter of a century, until in 2002 the AAVSO’s computerized chart-plotting program began to generate standard charts.

Chart distribution was a less creative but no less vital task. Williams distributed charts from 1965–1967; Leonard Kalish 1967–1973 (he copied and distributed 21,000 charts during his term of service); Gary Wedemayer during the 1974–1980 interval; and finally Gerard Samolyk from 1981 until standard charts became available from AAVSO headquarters at the end of the visual era.

4. Ephemerides

Along with charts, the essential ingredient in the growth of the AAVSO EB program was the provision of predictions of future minima of target stars. Without predicted times of minima, observers could not know when to give their attention to an EB and obtain the needed run of estimates covering both branches of the eclipse light curve. Each observer could, of course, make these calculations for himself, but to do so for a large number of stars was neither appealing nor practical.

The first ephemerides were published in *Sky & Telescope* for the stars introduced in its pages. But these occasional listings included only one, two, or three stars, so on many nights there were no observable minima. As the number of charted stars increased, Williams was able to address this need by preparing and distributing a monthly table of predictions. In those pre-computer days, he used a desktop adding machine, beginning with the JD day and decimal of a known time of minimum for each star and simply adding its period value over and over again, then selecting the minima observable from North America and converting the JD days and decimals into calendar dates and UT times.

Fortunately, this formidable monthly chore was soon eliminated when the Computer Age dawned early for the AAVSO EB program. Observer Don Livingston had access to a computer at his place of employment. (Readers born after 1965 need to realize that in those days, computers were the size of automobiles and were possessed only by a few universities and large commercial enterprises.) He was able to program this machine to generate monthly tables of predicted minima almost instantly for any number of stars, and a major obstruction to the continued growth of the EB program was eliminated.

Livingston provided this vital service from 1967 to 1979. He was succeeded by Peter Taylor, 1980–1983, Paul Sventek 1984–1985, and Gerard Samolyk from 1986 through the remainder of the visual era (and continuing in the CCD era). Eventually, printed ephemerides were supplemented by more flexible, Web-based services, such as Shawn Dvorak's Eclipsing Binary Ephemeris Generator (www.rollinghillsobs.org), which can include an unlimited number of stars, select those that are visible during dark hours from each observer's location, indicate the orbital phase of each system at any particular time, and provide links to additional information.

5. Reduction and publication

One spur to the success of the AAVSO EB program was the publication of minima timings with the identity of the observer attached to each timing. This provided much more recognition than the traditional AAVSO observing program (a need now met by the Quick Look page and Light Curve Generator on the AAVSO Web site for all reported observations).

The reduction and publication of times of minima were initially handled by Ashbrook at *Sky & Telescope* until 1965, when he passed this responsibility to assistant editor Leif J. Robinson. The lists of minima timings were now too long for publication in *Sky & Telescope*, so Robinson began submitting lists to the *IBVS*. When *Sky & Telescope* withdrew from the EB program in 1969, chairman Baldwin assumed responsibility for both reduction and publication of data. He continued to publish the results in *IBVS* until that publication ceased to accept papers based on visual observations in 1973. Baldwin then shifted publication to the new *JAAVSO*, 1974–1978. Then from 1993–2007, Baldwin and Samolyk prepared a series of twelve monographs, *Observed Minima Timings of Eclipsing Binaries*. Each of the first eleven monographs included new times of minima for fifty stars. Each star's new timings were presented on a separate page, which included an O–C diagram showing all the accumulated timings plotted against a constant period, so readers could see each star's period variations at a glance. The final monograph included all remaining unpublished times of minima.

At first, and for many years, the classic tracing paper method was used to determine the times of mid-eclipse. This involved plotting the observations, tracing the plot on transparent paper, then flipping the tracing and moving it left and right over the original plot to find the position of best fit between the original and the reversed light curves. This simple graphical procedure is surprisingly effective but required an enormous investment of time to plot the thousands of estimates for hundreds of minima each year. Calculating the heliocentric correction for each timing was an additional burden, which was partly ameliorated by preparing graphs of the heliocentric corrections for each of the most commonly observed stars. The correction could be read off the graph for any day of the year without having to enter the long formula into a scientific calculator (with the potential for input errors).

After 1975, the flood of observations created a growing backlog of minima timings. Finally, in 1986, with the assistance of Ron Baldwin, the chairman's son, and Samolyk, the tracing paper procedure was computerized with a program running on an Apple II. After the times and estimates were entered and verified, the program read a sequential file of observations with each light curve separated by a delimiter. The program displayed the first light curve on the screen with a mirror image. The operator moved the mirror image back and forth using the arrow keys until the best fit was found. Hitting "enter" produced the time of minimum with heliocentric correction, saved that result to a file, and displayed the next light curve. Thanks to this program, a large number of light curves could be reduced in a single session.

6. The visual era ends

During most years of the visual era, one or two photoelectric observers submitted a very few high-precision minima timings. But the arduous nature of the observing procedures meant that PEP could never compete with visual timings in quantity, and most PEP observers were limited to stars brighter than about eighth magnitude. Then in 1994, Gilbert Lubcke submitted the first minimum timing derived from CCD observations. Five years later, ten CCD observers were contributing timings.

Image-based CCD photometry was much more efficient than PEP because the variable and comparison stars were recorded simultaneously and a new image could be taken and downloaded every few minutes. CCD images also recorded much fainter stars than could be reached by PEP with the same aperture. CCD timings could equal the precision of PEP timings if all the correct procedures were followed. The final step to victory for CCD cameras in the timing of EB minima was the advent of computer-controlled telescopes, which could acquire a field, take a prescribed number of timed images, then move to another field with little or no intervention by a human operator.

In 2002, twenty percent of the entries in *Observed Minima Timings of Eclipsing Binaries #7* were derived from CCD photometry. A year later, thirty-three percent of the timings in *Observed Minima Timings #8* were CCD. In 2004, the CCD timings in *Observed Minima Timings #9* still represented only a fraction of the total, but the minima lists for forty-eight of the fifty stars included CCD timings. This was the tipping point. When visual timings were the only data available, they were invaluable. But when CCD timings were also available, researchers would ignore the visual timings because the CCD timings were ten to one-hundred times more accurate. By 2005, automated telescopes with CCD cameras were providing at least one CCD timing (and often more) for almost every EB within reach of visual observers, and the visual era of the AAVSO program had reached its terminus.

The visual era of the AAVSO eclipsing binary program was highly productive. More than 17,000 times of minima were observed and published, and a continuous record of the period variations of hundreds of EBs was compiled. Periods and light-curve types were found for many new or unstudied EBs, and erroneous periods were corrected. Many amateur astronomers enjoyed the opportunity to contribute observations of real astrophysical interest and to see their timings used in research papers. Everyone who participated in the visual program can feel a justified sense of accomplishment, and many of those observers continue to advance eclipsing binary astronomy as CCD photometrists for the re-named Eclipsing Binary Section.

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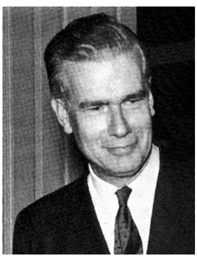

Figure 1. Joseph Ashbrook of Yale University and, later, *Sky & Telescope* editor, advised AAVSO Director Margaret Mayall on establishing a program to monitor eclipsing binary stars. From *Sky & Telescope*, October 1980; courtesy of *Sky & Telescope*.

Figure 2. David B. Williams, AAVSO Eclipsing Binary Program chair 1965–1969.

Figure 3. Marvin E. Baldwin (left), EB chair 1969–2007, with Gerard Samolyk, EB chair 2007–2009 and since 2009 co-chair with Gary Billings.