The History of AAVSO Charts, Part III: The Henden Era

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Abstract In this third paper covering the history of AAVSO charts I continue to describe not only the evolution of charts but the significant leap forward in all aspects of the chart production process that took place during the Henden Era, which started before Arne Henden became director and extends beyond his service as a Director of the AAVSO (2005–2015).

1. Introduction

When Arne Henden assumed the Directorship of the AAVSO in March of 2005, chart making had evolved to a computer-aided analog process producing charts which were also now available through the internet. While the chart production process still required manual labeling of the magnitudes and entering of the coordinates of comparison star data, the chart improvements were enabled by the use of planetarium software and art programs then being used by volunteer Michael A. Simonsen and staff member Aaron Price, as discussed in Malatesta *et al.* (2007).

Prior to Henden becoming director, Aaron Price, Vance Petriew (another volunteer), and Simonsen had already held numerous discussions on what tools and processes needed to be developed to meet chart needs going into the future. They recognized that ultimately some type of automated chart plotter needed to be developed and towards that goal they would have to establish a database of comparison stars to enable an automated chart plotter to function. The original concept for this database was actually one of the last contributions by Director Janet Mattei (Price 2018).

Price established and took charge of the Comparison Star Database Working Group to build a comparison star database in anticipation of an automated chart plotter, while Simonsen was put in charge of the AAVSO Chart Team to implement the guidelines, previously established by the International Chart Working Group, for the creation of new sequences and revisions of existing ones (Price *et al.* 2004a).

After a few months Price, during the AAVSO 2003 Spring Meeting, was able to persuade Petriew (during lunch on top of Kitt Peak), who was also a professional database manager, to take charge of the Comparison Star Database Working Group (Price 2018).

Shortly after assuming the Directorship, Henden informed everyone that he wanted the AAVSO out of the manual chart business by bringing the process fully into the digital age (Simonsen 2014). As Price noted:

> This is where he [Henden] was brilliant. Before this there was a little bit of residual grumbling and resistance-both among staff and membership. Arne's decisiveness put an end to it. At this point on, it was all hands on deck and everyone began working together (Price 2018).

The ultimate success of the process resulted in not only the original objective but a number of support elements as well. The whole of this endeavor involves a number of individual parts that were either in existence, being developed, or had yet to be created at the time Henden was appointed Director, and will be presented in a somewhat chronological order.

2. Chart error tracking tool (CHET)

A frustrating problem that had plagued chart making through the years was the tracking and fixing of errors on existing charts as reported by observers.

This problem was finally solved in 2003 when volunteer Chris Watson developed the web-based Chart Error Tracking Tool (CHET) that permitted observers to identify their problems and then have them tracked as sequence team members were able to respond.

The CHET tool underwent a significant revision in the fall of 2017 with the help of Phil Manno, who volunteered to convert the old code into the modern Django framework as used by other AAVSO tools; staff member Will McMain helped Manno get set up and started on the project. One of the more significant enhancements was an automatic response system for observers that would let them know when their reported errors were resolved.

3. Variable star database (VSD)

After assuming leadership in the Spring of 2003, Petriew established the guidelines for the Comparison Star Database Working Group's challenge of documenting into a digital database (called CompDB) all the comparison stars and variables that then existed.

Group members included Aaron Price, Vance Petriew, Rick Merriman, Keith Graham, Dan Taylor, Brian Skiff, Tim Hager, Carlo Gualdoni, Mike Simenson, Bob Stein, Roy Axelsen, Mark Munkacsy, Christopher Watson, Curt Schneider, Jim Bedient, Radu Corlan, Joe Maffei, Arno Van Werven, Pedro Pastor, and Dolores Sharples (Price et al. 2004b).

The CompDB project was completed in July 2006 and documented 4,184 charts with 35,820 unique stars, and consumed an estimated 10,000+ hours of volunteer effort by twenty volunteers (Petriew *et al.* 2007).

CompDB contained both identified and suspected variable stars (later moved to the VSX database) as well as comparison stars (estimated at ~30,500).

During October of 2006 Henden updated the photometry of about 22,000 of those comparison stars with the then best-known data.

The goal was to create a database that would then enable some form of automated chart production. To accomplish this, CompDB was converted into a relational database (the Variable Star Database, or VSD) which would contain only comparison stars and their associated information: coordinates, magnitude values and their errors, photometry source, and remarks.

To build VSD each comparison star in the existing CompDB was then assigned an AAVSO Unique Identifier (AUID) and migrated in.

AUIDs were created in the form of three triplets: ###-XXX-### without vowels being allowed for the XXX (alpha) portion. It was estimated that this Alpha-numeric format would allow for ~10 billion permutations (Petriew *et al.* 2007).

4. Variable star plotter (VSP)

With the development of VSD Henden felt quite confident that an automated chart plotter could now be developed and awarded a contract to Michael Koppelman and his company (Clockwork Active Media Systems (CAMS)) to build an Automated Chart Plotter (ACP) in 2006 with assistance from Chris Watson and Aaron Price.

The design goals were to create an online accessible system whereby the observer could enter a target name, a radius size of the field of view, and a magnitude limit which would generate an onscreen chart, of the specified size, showing visual magnitude values. Screen access to a photometry table (magnitude values for various filters, if available) for the target chart was included. As Price notes:

> Chris Watson designed the interface, I coded the interface software, and CAMS did the chart generation engine. I think a key development here was the development of the unique chart ID. That allowed anyone to recreate the exact details of any chart at any time (Price 2018).

In December of 2007, Henden announced:

> The Beta release of the Variable Star Plotter (VSP) was made just prior to the Spring Meeting. The VSP plotting engine has been ready for quite some time, but we needed to populate its internal database with all of the variable stars and sequence stars that were present on the existing charts before it was functional enough for the membership to use.... Due to its increased functionality, [it] should be used in preference to the chart archive (Henden 2007).

What a tremendous leap forward in chart making. The AAVSO no longer had the burden of producing paper charts as they had been for close to 100 years, thus freeing up considerable staff time.

Observers, through the internet, could now configure how they wanted a chart to be presented for any field of view (current configuration shown in Figure 1), then printed out on their home printer. In addition, they could also request a photometry table which was important to the growing field of CCD observing (Figure 2).

If there was an Achilles Heel to this incredible improvement, at the time, it was simply a lack of calibrated photometry to satisfy the rapidly increasing demands of the many observers who were now using the new tool.

Another major feature was that the observers could continue to choose the older black dot charts—the dots being in the correct position and sized in proportion to their V magnitude, or they could now select a digital sky image of the field of view showing all the stars captured by the camera, which was of great benefit to CCD observers.

5. International Variable Star Index (VSX)

During 2005, because of inadequacies of catalogs identifying variable stars, AAVSO Council Member Lew Cook suggested that an ad hoc group be formed to solve this problem. With David B. Williams as Chair, the members of this group included Aaron Price, Mike Simonsen, Vance Petriew, John Greaves, Brian Skiff, Bill Gray, and Arne Henden (Williams and Saladyga 2011).

Simonsen then enlisted amateur astronomer Christopher Watson (CHET creator), who conceptualized and outlined a database of variable star information that could easily be updated. After installing his system on a private site, Watson invited Henden to explore and critique it; that action quickly drew in the rest of the ad hoc group to explore this new tool (Williams and Saladyga 2011).

The final product was the VSX database, which could also qualify as a global clearing house database for all the up-to-date information available on variable stars and suspected variable stars, and insure that naming conflicts were either avoided or simply included by reference as an alternate name. Additionally, this database could assign the previously described (section 3) AUIDs to known and suspected variables.

While a number of volunteers have served on the VSX team through the years, current active members are Patrick Wils and Sebastián Otero (both of whom were also original participants in the ad hoc group) as well as Klaus Bernhard and Patrick Schmeer. This team keeps VSX continuously updated with newly discovered variables as well as new information for existing database variable stars (Otero 2018).

As of the first part of September 2018, VSX contained data on 542,610 variable stars.

VSX also plays another important role in that neither SEQPLOT (see section 7) nor the VSP will recognize a variable star name unless it exists in VSX and has been assigned an AUID. In addition, observers are not able to report observations unless the target is both in VSX and has been assigned an AUID.

6. Sequence team

With the development of VSP (renamed from ACP), there was no longer any need to continue the Chart Team, as VSP could produce a chart for any coordinates entered. What was now required was a group of volunteers to create sequences

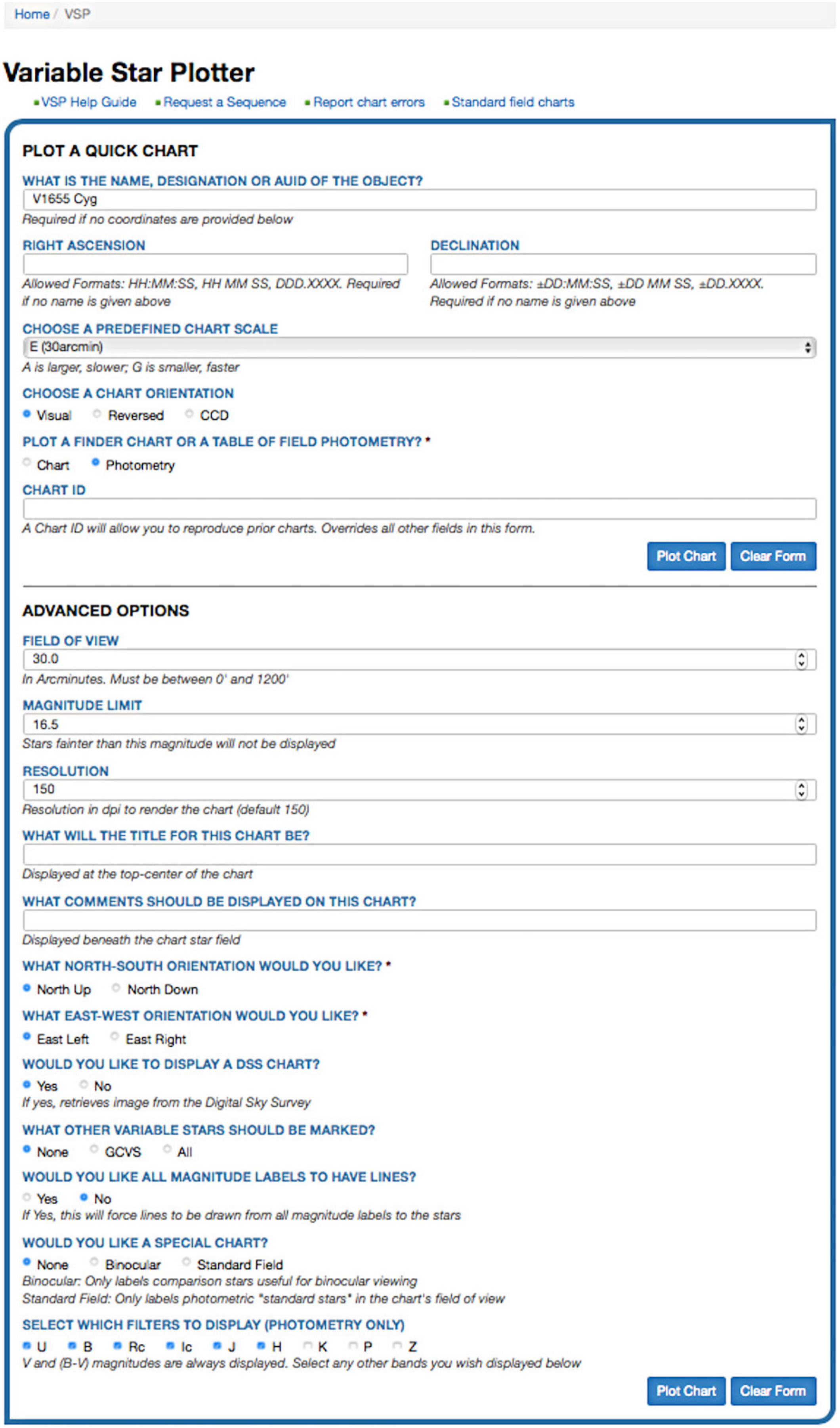

Figure 1. VSP options.

Variable Star Plotter

■ Plot Another Chart ■ Star Chart for this Table

Field photometry **for V1655 Cyg** from the AAVSO Variable Star Database

Data includes all comparison stars within 0.25° of RA: **20:25:24.02 [306.35008°]** & Dec: **38:42:35.6 [38.70989°]**

Report this sequence as **X23135PR** in the chart field of your observation report.

AUID	RA	Dec	Label	B	V	B-V	Rc	Ic
000-BMS-452	20:25:18.30 [306.32626343°]	38:37:44.3 [38.6289711°]	**109**	11.454 (0.041)[29]	10.894 (0.022)[29]	0.560 (0.047)	10.506 (0.028)[29]	10.142 (0.033)[29]
000-BMS-455	20:26:04.72 [306.51965332°]	38:43:29.9 [38.72497177°]	**111**	11.614 (0.071)[29]	11.106 (0.044)[29]	0.508 (0.084)	10.738 (0.051)[29]	10.392 (0.056)[29]
000-BMS-456	20:24:57.68 [306.24032593°]	38:49:50.5 [38.83069611°]	**116**	12.558 (0.077)[29]	11.603 (0.048)[29]	0.955 (0.091)	11.044 (0.052)[29]	10.523 (0.056)[29]
000-BMS-457	20:25:35.33 [306.3972168°]	38:44:16.8 [38.73799896°]	**122**	12.876 (0.073)[29]	12.196 (0.043)[29]	0.680 (0.085)	11.767 (0.055)[29]	11.365 (0.065)[29]
000-BMS-453	20:25:31.57 [306.38153076°]	38:42:24.6 [38.70683289°]	**124**	13.015 (0.061)[29]	12.419 (0.037)[29]	0.596 (0.071)	12.037 (0.046)[29]	11.678 (0.054)[29]
000-BMS-460	20:25:36.18 [306.40075684°]	38:46:33.8 [38.77605438°]	**126**	13.222 (0.076)[29]	12.641 (0.050)[29]	0.581 (0.091)	12.283 (0.056)[29]	11.946 (0.062)[29]
000-BMS-454	20:25:07.05 [306.27938843°]	38:45:01.8 [38.75049973°]	**129**	13.489 (0.078)[29]	12.938 (0.048)[29]	0.551 (0.092)	12.547 (0.050)[29]	12.180 (0.052)[29]
000-BMS-461	20:25:56.55 [306.48562622°]	38:43:56.2 [38.73227692°]	**133**	14.169 (0.075)[29]	13.342 (0.047)[29]	0.827 (0.089)	12.840 (0.061)[29]	12.371 (0.072)[29]
000-BMS-459	20:25:11.21 [306.29672241°]	38:43:40.8 [38.72800064°]	**135**	14.138 (0.069)[29]	13.529 (0.046)[29]	0.609 (0.083)	13.130 (0.047)[29]	12.756 (0.047)[29]

Figure 2. Photometry table from a VSP request.

(photometry values) for any field of view for which an observer would have an interest.

Therefore, the old Chart Team was finally disbanded (their last batch of new paper charts was released in March of 2006), and a new reconfigured team was created by Henden and Simonsen (Chair) in 2008 known as the Sequence Team.

The primary purpose of the Sequence Team was not to create charts, as such, but to create calibrated sequences which would cover specific field of view sizes so that observers could evaluate any target's magnitude that would fall within a given specific field of view using their own chart created and printed using the VSP.

Since the completion of the initial population of the VSD database, all new sequences have subsequently been loaded into VSD by Sequence Team members, eventually primarily using the SEQPLOT tool (section 7) with a heavy dependency upon APASS (AAVSO Photometric All-Sky Survey ~10–16.5V) calibrations.

Currently, in addition, when appropriate, calibration data from BSM (Bright Star Monitor ~6.3–13V), GCPD (General Catalogue of Photometric Data ~0–6.5V), NOFS (Naval Observatory Flagstaff aka Henden ~13–18.7V), SRO (Sonoita Research Observatory ~10.3–17V), and Tycho-2 (named after Tycho Brahe ~6.5–10.2V) survey data are also occasionally used within the SEQPLOT tool by team members.

Outside of SEQPLOT, team members will sometimes source calibration data from the following surveys, if needed: CMC15 (Carlsberg Meridian Catalog ~10V–14.4V), SDSS (Sloan Digital Sky Survey ~14.8–18.7V), and Pan-STARRS1 (Panoramic Survey Telescope & Rapid Response System ~14.5–20V).

In 2012 Simonsen had the team, including Otero, working on creating sequences specifically for the new AAVSO Binocular Program. A total of 153 bright semiregular and Mira stars in both hemispheres were selected, with specific comparison stars annotated for these specific variables' sequences so that only those comparison stars would appear in the larger field of views encompassed by binoculars when the Binocular chart option in the VSP was selected (Simonsen 2014).

While some twenty individuals have been involved with the Sequence Team efforts since its inception, current active team members are Tom Bretl, Tim Crawford, Robert Fidrich, Jim Jones, Mike Poxon, and Brad Walter. Bretl, Crawford, Fidrich, and Jones have served on the team since at least 2009.

Since record keeping started in late 2008 (through September 8, 2018) the Sequence Team has created 3,592 new sequences and revised/extended some 2,129 existing sequences, for a total of 5,721 new or revised sequences. Bretl, Crawford, and Jones together have accounted for 84.4% of all sequence work during this period.

The comparison star database (VSD) has now grown to ~86,000 stars (unique AUIDs), through the end of August 2018, up from the ~30,500 that existed in 2007.

Team member Bretl was appointed to Chair the Sequence Team in 2015 by Simonsen who needed more time for other responsibilities. Bretl continues to serve in that capacity today.

7. SEQPLOT

During March of 2007, Aaron Price wrote a script so that sequence team members could load sequences directly into the VSD database; sequences were required to be presented in a text file for uploading, in a specified format (listed in its current configuration):

#Comp,RA,m,s,Dec,m,s,V,Verr,B-V,B-Verr,U-B,U-Berr,V-R,V-Rerr,R-I,R-Ierr,V-I,V-Ierr,Source,#Comments

This was somewhat of a labor-intensive process for the sequence team volunteers as they would have to locate a suitable survey either by possessing documents previously assembled, i.e., Henden USNO data, published papers, or an internet source of a specific survey or surveys, such as Tycho-2 and ASAS. The next step was to generate a listing of potential comparison stars from a specific survey, then choose a potential candidate and check it via a digital sky image (VSP or Aladin) to avoid doubles, and then once selected, to convert and transcribe the available data into the above format following previously established rules regarding how comps were to be selected. As Henden recalls:

> I developed a FORTRAN program called hfind in the 1990s, that charted all of the then-available NOFS calibration data and created star charts, along with an interactive cursor to extract photometric data for each plotted star. I demonstrated this program to Janet [Mattei] around 1998, as she was concerned over the large programming task to change from hand-drawn charts with an embedded sequence table. She then assigned her postdoc [staff member] (George Hawkins) to create an IDL chart-plotter, but had not made any progress in working with sequences before her passing (Henden 2018).
>
> Towards the end of 2008, I decided that we needed an easier method of creating sequences, now that the chart generator was working so well. [AAVSO staff member] Sara Beck had been learning JAVA with [staff member] Kate Davis, and when Sara returned from Tahiti in early 2009, I assigned her the task of essentially porting my hfind program into JAVA. She built a database using my calibrated star tables, and then created the query and plotting program to read that database and plot calibrated stars in a fashion similar to hfind (Henden 2018).

Sara Beck notes:

> Henden sent me an additional email in mid-February 2009 describing how the size of the star dots should be computed and the R.A/Dec. should be converted to the tangent plane. The database was set up a week later, and I created the download page on February 27th. Henden then announced it to the Sequence Team the same day (Beck 2018).

While the sequence catalog (Seqcat) was initially populated with only a few calibrated surveys of limited sky coverage (GCPD, Henden, SRO, and Tycho-2, for example), this was a major labor-saving tool; these surveys were shortly followed by SRO, BSM, and APASS (all described in section 6).

The sequence team member is presented with a list of calibrated data surveys by Name and ID from which they choose which survey they want to check (the current configuration is shown in Figure 3).

After entering the variable star name or its coordinates, search radius, and limiting magnitude, the sequence team member is presented with a screen image showing the relative distribution of potential comp stars within the requested field of view. The variable stars are displayed as yellow, and then the potential comparison stars as either blue, green, or red, depending upon their B–V values. When a sequence team member clicks on a potential comparison star they are presented with the coordinates and magnitude values (V and B–V) as well as the number of calibrated observations and the source ID (Figure 4). To add a comparison star to a sequence, the team member has a button to click for any selected star (Send to File) that will then add all the data to a text file, in the correct format as shown earlier, for uploading to VSD.

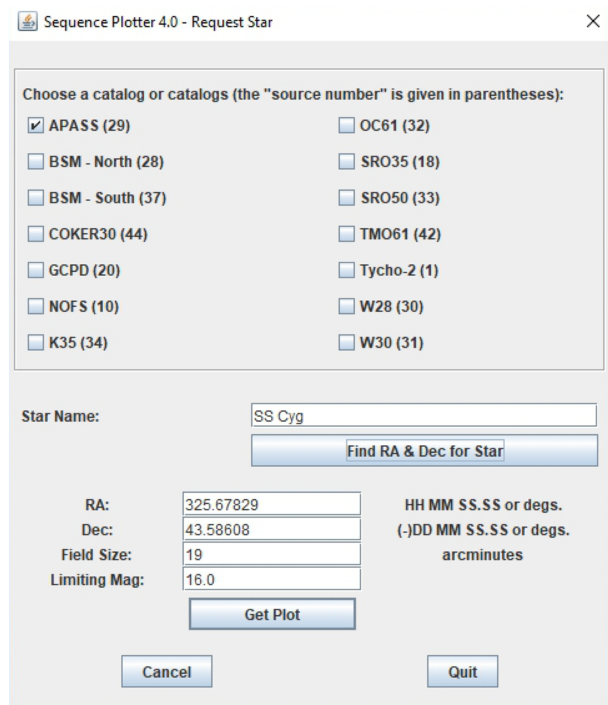

Figure 3. Current SEQPLOT Initial Entry Screen.

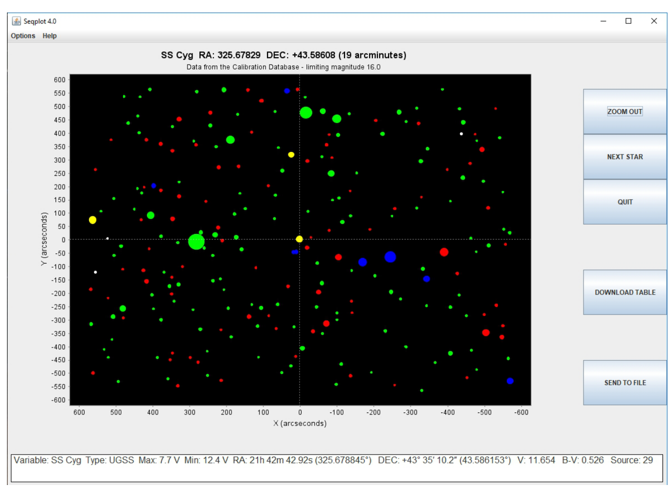

Figure 4. Current SEQPLOT Sequence Building Screen.

8. All-sky photometry

With the tools now well established for observer printing of charts and creation of sequences, the greatest deficiency was the absence of all-sky calibrated data needed for the Sequence Team to be able to create new sequences as were increasingly being requested by observers.

Henden had been a major contributor of calibrated data, as time permitted (starting in the 1990s), while employed at the Naval Observatory in Flagstaff, Arizona. With his appointment as Director of the AAVSO in 2005, this source ceased to exist. Henden describes the turn of events:

> However, the AAVSO became a member of the Sonoita Research Observatory (SRO) consortium in 2005. I used the Celestron C14 telescope for field calibrations for the next few years, primarily for CV and Mira fields. In 2008, two telescopes became available from the estate of Paul Wright. Sited near Cloudcroft, NM, at Tom Krajci's observatory, these telescopes and SRO formed the basis of the AAVSOnet robotic telescope network. While time was made available to the membership, all three telescopes also provided calibration photometry for AAVSO campaigns.
>
> In November 2009, the AAVSO submitted a proposal to NSF to cover the eclipse of epsilon Aurigae, a very long-period binary system. At 3rd magnitude, it was too bright to monitor with the AAVSOnet telescopes. I designed a new, inexpensive system consisting of a wide-field astrographic refractor, SBIG CCD camera and Celestron GOTO mount, and obtained permission from Krajci to site the system at his observatory. This "Bright Star Monitor" (BSM) was specified to be capable of imaging Polaris at V = 2, with a primary emphasis of monitoring the ε Aur eclipse. During the Fall 2009 AAVSO Council meeting, I presented the concept to the Council and got permission to proceed. Donations were obtained from D. Starkey, D. Welch, J. Bedient, M. Simonsen, G. Walker, K. Mogul. and D. Sworin for the equipment purchase. It saw first light October 12, 2009.
>
> The original BSM system was followed by others in Australia, Massachusetts, and Hawaii, all funded by donations from individuals. This BSM network was heavily used to provide field calibrations for the brighter stars in the AAVSO program, as well as monitoring bright variables (and acquiring thousands of data points during the eps Aur eclipse).
>
> Since many nights were calibrated using Landolt standards, and every star in every frame was measured by an automated pipeline, a database of all calibrated stars in all nightly fields was created. This file eventually contained about one million bright stars across the sky in isolated 3-square-degree patches.
>
> Similar databases were created for the other AAVSOnet telescopes, such as SRO. These individual databases were gathered together into the Seqcat database used by seqplot by the Sequence Team Members.
>
> I wrote an article about the AAVSO for *Sky & Telescope* for their November 2009 issue. Robert Ayers, an amateur in California, read the article and contacted me about possible financial contribution towards pro-am collaboration. After much discussion, a proposal was submitted to his Robert Martin Ayers Sciences Fund to create the AAVSO Photometric All-Sky Survey (APASS). This was a long-time dream of mine, to provide calibrated photometry in every part of the sky, so that the tedious process of all-sky calibration of individual FOVs could be avoided. An APASS site in both the northern and southern hemispheres were envisioned, to cover the entire sky from 10<V<17 mag in multiple passbands. The northern site saw first light on November 6, 2009, and was sited at Tom Smith's observatory in Weed, NM. The southern site saw first light November 2, 2010 at the PROMPT complex at CTIO (La Serena, Chile). These sites typically calibrated 500 square degrees per photometric night in five passbands (Johnson B,V, and Sloan g,r,i).
>
> A team of professional collaborators (D. Welch, D. Terrell, S. Levine, A. Henden), software vendors (such as B. Denny and D. George) and volunteer amateurs (such as T. Smith, A. Sliski, and J. Gross) helped set up the system and monitor its progress. Multiple attempts at obtaining NSF funding for the project were made, with a grant made in 2014.
>
> The first data release from APASS occurred in September, 2010 and included about 4 million northern stars. Since then, 9 other releases have been issued, covering 99% of the sky.
>
> APASS was incorporated into Seqcat, starting with DR1, and forms the majority of the database at this time (Henden 2018).

APASS Data release 10 was installed in October of 2018, to be followed by DR 11 which will have about 100 additional nights of data with continued analysis improvement. It is anticipated that in about another year the final APASS data release, DR 12, will take place, which will include some missing Northern Hemisphere areas which are currently being covered as well as improved data analysis.

9. Request comparison stars for variable star charts

During 2010, sequence team member Tim Crawford realized that observers needed a way to make requests (as staff and team members were already able to do) for sequences for targets of interest that lacked comparison stars, and subsequently created a proposal to accomplish this. Team leader Simonsen and the AAVSO Director Henden readily approved this proposal and the staff time for creation of a web page for observers to make their requests.

The first sequence request was received on December 16, 2010 from Denis Denisenko (Russian Federation), and the 1,000th on November 25, 2015 from Stephen Hovell (New Zealand).

Through the end of August 2018, the Sequence Team has received some 1,963 requests from observers for new sequences. This total does not include staff requests for new sequences nor those self-generated by Sequence Team members.

10. Conclusions

Foremost, it needs to be recognized that while the important development of the various databases and tools and the creation of the Variable Star Plotter are significant for both current observers and future observers for producing charts and photometry tables, they would all have a limited and confining purpose were it not for the availability of calibrated data, principally APASS, that allows for the overwhelming majority of the sky in both hemispheres to be able to have sequences available in the ~10–16.5V range.

The APASS (as well as BSM) effort was a visionary triumph for Henden and quite an amazing feat given the limited resources available and the overworked team of both staff members and volunteers that aided Henden.

With the increasing availability of the fainter Pan-STARRS1 data (~14.5–20V) and the final release of APASS data, future generations of observers should never have a problem securing a sequence for any existing variable star or future variable star discovery, in either hemisphere.

Without the appointment of Arne Henden as the Director of the AAVSO, in 2005, I am skeptical that the charting/sequence process would have advanced to become as sophisticated and reliable as it is today. We are all indebted to Henden for his many past and continued tireless contributions to the process.

11. Acknowledgements

At the AAVSO Fall Meeting in 2014 Simonsen presented a PowerPoint presentation titled “History of AAVSO Charts III: the Henden Era.” As future events unfolded, Simonsen was unable to advance this outline to a paper, which prompted me to undertake the project. I am indebted to Mike for both his initial outline as well as for bringing me on the chart team in 2007 and showing great patience as a mentor.

I owe a very large thank you to Arne Henden for his review of this paper and for allowing me to directly quote a number of his contributions. In addition, Aaron Price is to be acknowledged and thanked for also reviewing this paper and for allowing me to directly quote him several times.

I apologize if I have overlooked any of the many staff and volunteer contributors to the various portions of this process. I have attempted in good faith to recognize as many of you as I could identify.

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