# Algorithms + Observations = VStar

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**Abstract** VSTAR is a multi-platform, free, open source application for visualizing and analyzing time-series data. It is primarily intended for use with variable star observations, permitting light curves and phase plots to be created, viewed in tabular form, and filtered. Period search and model creation are supported. Wavelet-based time-frequency analysis permits change in period over time to be investigated. Data can be loaded from the AAVSO International Database or files of various formats. VSTAR's feature set can be expanded via plug-ins, for example, to read Kepler mission data. This article explores VSTAR's beginnings from a conversation with Arne Henden in 2008 to its development since 2009 in the context of the AAVSO's Citizen Sky Project. Science examples are provided and anticipated future directions are outlined.

## 1. Introduction

A conversation with AAVSO Director Arne Hendon at the 23rd National Australian Convention of Amateur Astronomers (NACAA ) in 2008 planted the seed for a successor to Grant Foster's DOS-based VSTAR program (Figure 1), initially created for use with the AAVSO's *Hands-on Astrophysics* educational material, later renamed *Variable Star Astronomy*. The motivation for the author was simple: the opportunity to develop an easy to use, powerful data visualization and analysis tool that amateur and professional astronomers would want to use.

Correspondence over the next year culminated in AAVSO staff (including Aaron Price, Arne Henden, and Sara Beck) coming up with an initial specification for a new Java-based multi-platform (WINDOWS, MAC OS X, LINUX, OPENSOLARIS) implementation of VSTAR. Regular communication with Sara Beck commenced in May 2009. Since then, VSTAR development has consumed most of the author's spare time, family and other commitments permitting, and brought a group of passionate people together.

## 2. Feature overview

Fundamentally, VSTAR's purpose is to permit time series data (ostensibly variable star observations) from a variety of sources to be loaded and analyzed. The initial specification called for data to be loaded from the AAVSO International Database (AID), files conforming to the AAVSO Download

File format, and a simple subset of the latter for personal observations (JD, magnitude, and optionally: error, observer code, and validation flag).

Apart from light curve and phase plot creation, the loaded dataset can be viewed and searched in tabular form. Selection of an observation on a light curve or phase plot is synchronized with observation table row selection, and the reverse is also true. Lists of favorite AID objects can be created. Discrepant observations can be excluded and/or reported to AAVSO Headquarters.

Observation bands can be displayed or hidden through a plot control dialog, which also affects what is seen by default in the observation table. Simple filters can be defined to yield a new series for analysis and the observation table can be searched using regular expressions. See Figures 2 and 3 for examples of different views. Plots can be zoomed and panned. The usual print and save functions are provided.

Binned means can be created for the raw light curve or phased data. Error bars for means and observations can optionally be displayed. An information window shows a breakdown of the loaded dataset by band and a "signal significance" statistic in the form of ANOVA for the band that is the current source for binned means.

The other broad category of functionality is analysis. The first sub-category is period analysis. In VSTAR, this is an implementation of the Date Compensated Discrete Fourier Transform (DCDFT) algorithm (Ferraz-Mello 1981), yielding a power spectrum and table of "top-hits" for a specified series, frequency or period range, and resolution.

From within the DCDFT result window, a phase plot can be created. In addition, one or more periods each with one or more harmonics can be selected to create a model. A model's Fourier coefficients can be viewed along with relative amplitudes and phases. Multiple periods can optionally be refined via the CLEANest (Foster 1995) algorithm. When a model is created, it is also subtracted from the series on which the DCDFT was performed to yield a second, "residuals," series. DCDFT can then be applied to these residuals to look for further signals (periods), a process often called "pre-whitening." See Figure 8 for a sample DCDFT power spectrum and phase plot resulting from a top-hit selection.

The second major analysis capability is time-frequency analysis in the form of the Weighted Wavelet Z-Transform (WWZ; Foster 1996). The user specifies a series, period or frequency range, and resolution, and an analysis of change in period over time is the result. This can be viewed as a 2D graph, a contour plot, a rotatable 3D graph, or in tabular form. Periods can be selected for phase plot creation. Figure 4 shows period change for T UMi between 1913 and 2009. Here the color represents the WWZ statistic, the strength of a periodicity, at a particular time. This example is discussed in Foster (2010).

Another kind of model that can be created is a polynomial fit, along with the corresponding residuals series (for example, for finding the minimum or maximum magnitude in a cycle of a Mira dataset). Figure 5 shows a polynomial fit of degree 7 for o Cet in the JD range 2451460 to 2451560 along with a 5-day binned means series. The cross-hairs are on the highest point of the curve, at a magnitude of around 3.315 and a JD of around 2451492.8. This example is based upon one found in Foster (2010).

VSTAR's in-built feature set can be enhanced by creating plug-ins (in JAVA). This will be elaborated on in another section. The beginnings of a scripting capability exist, permitting certain operations to be automated.

## 3. Early development

The original specification led to an initial round of questions. A key decision early on was to move the content from a WORD document to a Wiki (initially hosted by AAVSO). This facilitated a dialogue between the author and the AAVSO through Sara Beck, resulting in the Wiki being annotated with questions and answers. By the end of May 2009, a set of requirements was created that determined what would be developed during phase one.

It was decided that the project would be hosted on SourceForge. AAVSO staff member Richard Kinne helped establish this and argued that VSTAR should be licensed under the Affero GNU Public License, a web-deployment-friendly version of the normal GNU Public License. Feedback on early user interface prototypes was sought from AAVSO staff members.

It was rewarding to reach the point at which VSTAR could be used to load a dataset (for δ Cep) and create a phase plot. Although a simple feature, it was at this point that the author began to glimpse how powerful a tool like this could be.

## 4. Citizen Sky team

Leading up to the first Citizen Sky workshop in 2009, the VSTAR Software Development team became the first Citizen Sky project, facilitated by Rebecca Turner.

In July 2009, Michael Umbricht, an astronomer at Brown University's Ladd Observatory, contacted the author through Citizen Sky to say that he wanted to help on the project as a tester. After about three months of initial development, Michael's domain knowledge and early feedback on the proto-VSTAR was valuable. Leading up to the first workshop and for quite a few months thereafter, Michael played a key role in testing, promoting VSTAR, and trialling it in a classroom setting.

Soon after the first workshop (around September 2009) Adam Weber joined. He and the author had worthwhile design and implementation discussions. Adam contributed a number of bug fixes and helped to improve the look and feel of VSTAR, especially under MAC OS X.

Nico Camargo, a young artist living in Chicago, attended the first Citizen

Sky workshop and we corresponded afterward. He has played an important role in improving VSTAR's appearance by creating toolbar button and desktop icons. His willingness to help, often at short notice, has been much appreciated.

Over the lifetime of the project numerous people have expressed interest in contributing. Following through was not always possible due to other commitments or because the time and effort required to learn enough about the existing code base to make a contribution was prohibitive. Many who did not directly contribute to development or test often still provided suggestions or encouragement. The Citizen Sky VSTAR development team forum captures the team's interactions. Testing and documentation are not especially popular and it was not generally easy to interest people in these activities. As the team size grew, communication overheads rose, with less time available to the author for software development, compared with the frenetic pace of the first few months. Overheads reduced as the team stabilized.

The most important aspect of the team was the confluence of diverse skills, knowledge, and experience. As lead developer, the author could defer to others with greater domain expertise or artistic skill. Communication media such as Wiki, instant messaging, email, and occasional calls largely compensated for the distance across the Pacific separating the author from most of the team. Questions left with Sara and other team members would often be answered during the author's night. An AAS poster paper covers the team aspect in more detail (Henden *et al.* 2010).

## 5. Workshops and talks

### 5.1. Citizen Sky 1

The first Citizen Sky workshop, held at the Adler planetarium in Chicago in August 2009, was an opportunity to receive early feedback from a broader audience about the early implementation of VSTAR. Feedback from Arne Henden and others led to improvements and bug fixes before the first internal deployment to the Citizen Sky VSTAR development team on November 13, 2009.

### 5.2. NACAA 2010 workshop

The National Australian Convention of Amateur Astronomers (NACAA) is held every two years and has already been mentioned in relation to its role in getting VSTAR started in 2008. Two years later the author ran a full-day workshop at the 24th NACAA. Version 2.0 was released and announced on the AAVSO website in conjunction with that event.

Feedback from Australian and New Zealand amateurs and members of Variable Stars South (VSS) led to several new SourceForge tracker items. It also reinforced to the author certain user interface changes that would improve the end user experience, primarily by increasing the amount of real estate for plots and tables in the main window and moving secondary functions to dialogs (see Figures 6 and 7).

5.3. Citizen Sky 2

At the second Citizen Sky workshop, held at the California Academy of Sciences, San Francisco, in September 2010, the author gave a presentation showing how VSTAR could be used to carry out period analysis, minima identification with a polynomial fit, and an overview of other capabilities added since 2009. Again, the resulting feedback was important for improving the tool.

Leading up to this workshop, Aaron Price created the "5 Star Tutorial" for data analysis, a companion to the Citizen Sky "10 Star Tutorial," for observation of variable stars. The 5 Star Tutorial showed how to use VSTAR to create a binned means series, carry out period search with DCDFT, and create phase plots.

Heinz Bernd-Eggenstein was present at the workshop and showed the author a bug in which VSTAR misbehaved with numeric input in the presence of a German locale being set on the host operating system. Fixing this seemingly simple problem took some weeks after the workshop. Additional locale improvements are on the roadmap, such as providing language specific (for example, German, Spanish, and Portuguese) versions of VSTAR.

5.4. NACAA 2012 update

Four years after the initial conversation with Arne Henden, a talk and demonstration of progress since the 2010 full day workshop was given at the 2nd Variable Stars South Colloquium held in conjunction with the 25th NACAA in Brisbane.

Time spent during breaks with VSS members, in particular Mark Blackford, David Moriarty, Alan Plummer, and Tom Richards, was beneficial as we talked about their use of VSTAR. For example, the need for an ASAS data source plug-in was expressed.

## 6. From FORTRAN to JAVA

Even before development of VSTAR had begun, Matthew Templeton pointed the author to a paper about the DCDFT algorithm (Ferraz-Mello 1981). Grant Foster had previously written an implementation of DCDFT in BASIC which was subsequently converted to a FORTRAN version by Matthew as part of AAVSO's TS console-based program.

When the time came to implement DCDFT for VSTAR, there were a few choices:

- Implement DCDFT purely based upon the published literature.
- Convert the FORTRAN TS code to JAVA. The author experimented with FORTRAN to JAVA translators, but at the time, none was found to be without important bugs.

- Convert the FORTRAN TS code to C and call from VSTAR as "native methods."
- Convert the FORTRAN TS code to C and then to JAVA.

FORTRAN to C translators exist, in particular F2C. This was made use of in order to be able to source-level debug the TS code in C form when possible bugs in the FORTRAN code were found. The code generated by such translators tends to be cryptic and have dependencies upon special libraries. Calling C code through JAVA's native interface mechanism would have required natively compiled libraries for each operating system, somewhat antithetical to VSTAR's generally platform-independent implementation.

Other than this, there are sufficient incompatibilities between the console and text menu driven nature and data structures of the TS program compared with VSTAR's internals and user interface, that in the end, a mixture of the first and second options was employed.

First, the appropriate literature was read to get an understanding of DCDFT (Ferraz-Mello 1981). Next, a PERL script was written to perform a partial translation of the TS FORTRAN code into JAVA. Next, each line of emitted JAVA code was inspected for logical equivalence with the FORTRAN code. The core algorithms were translated and extracted in this way and exposed to the rest of VSTAR through the appropriate menu items and dialog boxes. For testing purposes, TS was treated as a reference implementation for DCDFT. Unit tests were written for the JAVA implementation of the algorithm and checked (automatically, after some initial manual checking) against the results generated by TS for the same input. The same strategy was used to implement and test WWZ in VSTAR.

There is a difference in emphasis between implementing and testing algorithms from a publication such as Meeus (1991)—which was used for JD calculations in VSTAR—and doing so from the literature. The purpose of a book such as Meeus is to unambiguously describe an algorithm and provide at least minimal test cases. A paper that describes an algorithm does not have quite the same obligation. Hence the approach of using "battled-tested" FORTRAN as a reference implementation and semi-automated translation as opposed to writing from scratch from the literature, while making use of it to bolster understanding of the algorithm. In the end, the key benefit is that the powerful functionality of the FORTRAN TS and WWZ code has been made available in VSTAR, and along the way, some bugs were uncovered in the original FORTRAN code.

## 7. Plug-ins

VSTAR plug-ins can be created using the JAVA programming language (or in fact, any language that can be compiled to JAVA VIRTUAL MACHINE class files) in order to:

- Load observations from an arbitrary source.
- Perform a custom dataset filtering operation.
- Implement a new period analysis algorithm.
- Carry out an arbitrary operation on the loaded dataset.
- Create a general purpose tool.
- Implement a model creation tool.

Perhaps not too surprising is that observation source plug-ins have so far been the most commonly written or requested, since this makes it possible to load datasets from more diverse sources than those defined by the AAVSO.

To date, observation source plug-ins have been written for Kepler mission public data release FITS files and SuperWASP survey FITS files. Both of these were written in collaboration with Doug Welch. Other users such as Ken Mogul and Alan Plummer prompted the development of an AAVSO simple and extended upload file format observation source plug-in. This format can be hand-crafted or generated by an application such as VPHOT for use in uploading multiple observations to the AAVSO International Database. Some plug-ins, if commonly used like this one, may eventually be added into the core of VSTAR's code base.

An example of the second category was a plug-in written by Sara Beck to show which observations in a loaded dataset were made by observers in, for example, Ireland.

As far as the author is aware, no period analysis plug-ins have been written yet, but two candidates are AoV (Schwarzenberg-Czerny 1989) and Fast Chi-squared (Palmer 2009). Internally, DCDFT and WWZ are treated as plug-ins, implementing the required interfaces, the only difference being that they are not dynamically loaded when VSTAR starts.

An example of the "arbitrary operation" plug-in type was created by the author when AAVSO member Mike Simonsen expressed a need to select datapoints on a light curve plot to determine mean time between selected observations (along with mean magnitude). An example of the last plug-in category is a JD to calendar date calculator. The VSTAR plug-in library (http://www.aavso.org/vstar-plugin-library) and the VSTAR webpage (http://www.aavso.org/v-star-overview) can be consulted for more information.

## 8. Deployment

JAVA WEBSTART™ is the deployment mechanism used when launching VSTAR from the AAVSO web page and remains the easiest way to begin using VSTAR. WEBSTART™ imposes "security constraints" similar to that imposed by a JAVA applet. It took some time to make VSTAR work properly within these constraints, especially in the presence of dynamically loaded plug-ins.

For each formal release, there were one or more testing releases made available to the Citizen Sky team through WEBSTART™. Each formal release has been accompanied by a downloadable archive (from SourceForge) that can be unzipped and run as a normal local application. More recently, operating-system specific launcher programs/scripts were added to improve the local run-time experience, in particular by making start-up memory allocation equivalent to the WEBSTART™ deployment and by adding a desktop icon for DOS/WINDOWS and MAC OS X.

## 9. Science examples

This section gives brief examples of how VSTAR has been used for Citizen Science. These examples are not exhaustive, but they are representative.

### 9.1. Cepheid identification

In an example of professional-amateur collaboration, amateur astronomer Ken Mogul has partnered with Doug Welch, a professional astronomer at McMaster University, on a long-term project using the robotic telescope network AAVSOnet to obtain high-quality photometric time series of Type 2 Cepheids in Sloan griz filters. Ambiguously classified variables (CEP, CEP:) were also included to ensure that their classifications could be improved (Welch 2012). VPHOT is used to process images and VSTAR is used to help eliminate targets that don't meet the project criteria. In Ken's words: "I have also been able to data mine the data for new variables outside the goal of the project. VSTAR has enabled me to make intelligent suggestions to the professional on what to look at and what to dismiss thereby saving the professional time to focus on the big picture" (Mogul 2012).

By using VPHOT and VSTAR together, Ken was easily and quickly able to first reduce the data for every other star, apart from the original target, in the field-of-view being studied, to look for possible variability. Then VSTAR's DCDFT and phase plot features (see Figure 8) enabled him to immediately phase the data into a classification-revealing light curve, such as in the example in Figure 8 of star 2MASS J03145502+5618172 (Mogul 2012). Ken was also able to reclassify GV Aur as a Classical Cepheid as shown in Figure 9.

Again, in Ken's words: "Eventually with enough data, VSTAR will enable me to be at the center of the action conceptually, without my having to spend a great effort to learn and understand things like IRAF. These tools are a shining example of how to make citizen science a viable force going forward. AAVSOnet, VSTAR and VPHOT have enabled me, with no equipment…to go from observing to organizing to analyzing and drawing useful conclusions…with only a computer and Internet connection…a possibility which was almost unimaginable even a decade ago, except to the very far sighted" (Mogul 2012).

9.2. Kepler data mining

Using VSTAR's Kepler data source plug-in and DCDFT and phase plots, Kevin Alton has explored eclipsing variable star systems observed by the Kepler spacecraft, looking for changes in minima/maxima across cycles. According to Kevin, this is a prelude to potentially mapping magnetic activity cycles and/or starspot migration in selected contact binaries (Alton 2012).

9.3. Long term ε Aurigae light curve

Brian Kloppenborg has used VSTAR's WWZ feature to look for changing or multiple periods in ε Aur's long-term photometric archive light curve. Brian commented that nothing has been found so far, as others before him have discovered (Kloppenborg 2012). Brian's use of WWZ exposed a bug in the FORTRAN and JAVA implementation (in the presence of significant gaps in the data). This is now on the inevitable list of things to fix.

9.4. Light curves for illustration in articles

Articles containing light curves saved from VSTAR have appeared in *Australian Sky & Telescope* by VSS member Alan Plummer and by others in VSS newsletters and elsewhere.

9.5. Mira Fourier coefficient team (Citizen Sky)

Apart from acting as a testing ground for DCDFT, Fourier series modelling, and WWZ in VSTAR, the Citizen Sky Mira Fourier coefficient team needed to bulk-download around 400 Mira datasets of fixed duration from the AID. VSTAR can be scripted (only through JAVASCRIPT currently) to automate some operations, such as data file or AID dataset loading. This feature was used to bulk download these Mira observation datasets.

9.6. Period search and phase plots

As part of learning about variable star photometry and analysis in his work on the SPADES project (Richards 2012), VSS member David Moriarty has carried out period search with VSTAR on photometric data obtained for the contact eclipsing binary system TW Cru and compared it to period and epoch values found in GCVS, Dvorak, and Krakow repositories.

## 10. Future directions

Although still under active development, VSTAR is already proving to be a useful tool for activities ranging from simply exploring light curves in AID to analyzing photometric data so as to determine a star's period. The initial goal for VSTAR was to create a free, easy-to-use tool for basic variable star observation visualization and analysis. User anecdotes suggest that this has been achieved.

Much has been done, but there is still plenty to do. What follows gives some indication of VSTAR's future:

• Parallelization of DCDFT and WWZ to make use of multi-core machines with concurrent JAVA threads mapping to cores.

• Memory footprint reduction. For example, each observation data-point is represented by an object that consumes more memory than it should. Addressing this will permit larger data sets to be loaded.

• Better documentation, in the form of a user manual as opposed to the current minimal Help menu item and occasional articles.

• More analysis features, for example: time of minimum/maximum, for example, for eclipsing binary epoch determination; alternatives to DCDFT, such as AoV and Fast Chi-Squared. These can also be developed by others as plug-ins; O–C analysis; Lowess fit, for example, for minima determination (Foster 2010).

• AAVSO download files can be generated as lines of comma-, tab-, or space-separated values. Unless values are quoted, ambiguity is possible (for example, commas in comments fields). This has been flagged as an issue and will be pursued since some files contain lines that cannot be unambiguously parsed by VSTAR (or any tool), so must be omitted at load time and reported as erroneous to the user.

• Permit toggling between magnitude and flux values for particular kinds of analysis.

• Make plug-in installation and management a less manual process.

• Improve the quality of plots for publication.

• Localization (for example, Spanish, German, Portuguese, or Persian).

• Increasing the power of models, for example: addition of arbitrary terms, such as for observer bias (as permitted by TS); making it easier to accumulate periods throughout the process of pre-whitening for subsequent model creation; merging two or more existing models; model creation from WWZ.

• Although plug-ins can be created to perform arbitrary filtering operations, the current in-built filtering capability is limited to the equivalent of an expression language over a subset of an observation's fields, supporting conjunction (logical AND), relational operations (>, <, =, <=, >=), and negation. This could be made more powerful by permitting expressions containing disjunctions (logical OR) and allowing all observation fields to be used.

• The scripting API should grow to permit more operations to be automated.

- Replacement of direct AID database access with a web service. This would also open up programmatic access to AID to a broader range of applications and devices, but this is something that cannot be done in isolation and is a decision for AAVSO since it has infrastructure implications.
- Other data source plug-ins, such as for ASAS.
- Bug fixes! See the SourceForge tracker for these, the issues above, and others besides (https://sourceforge.net/projects/vstar).
- In general, the SourceForge tracker and change log (updated each release) will continue to document the process of change.

## 11. Acknowledgements

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Michael Umbricht, Adam Weber, Nico Camargo, Heinz Bernd-Eggenstein, Jaime Garcia, Doug Welch, Ken Mogul, and Mike Simonsen—VSTAR team members and users—provided feedback, assistance, testing, and encouragement. Thanks also to Grant Foster for writing his light curve analysis book (Foster 2010), introducing me to the R statistical analysis language, and for helpful technical discussions. These people have given generously of their time and talents in response to my questions.

Members of VSS have also provided encouragement, advice for future directions, and better still, have made use of it in their research (for example, Mark Blackford and David Moriarty).

A little more than two years after the VSTAR project started, I received email from Arne Henden to say that I was the recipient of the 2011 AAVSO Director's Award. Considering the previous recipients of this award, I am honored and humbled to have received this. Members of the VSTAR team, and others, helped to make this possible.

My supportive wife Karen and children Nicholas and Heather have become very tolerant of their husband's/father's nocturnal nature, especially over the last few years. Nicholas also helped with the DOS/WINDOWS launcher.

The author greatly appreciates the opportunity to develop VSTAR, to participate in the Citizen Sky and AAVSO communities, and to attend both Citizen Sky workshops.

The title for this paper was inspired by a 1976 book by computer scientist Niklaus Wirth—*Algorithms + Data Structures = Programs.*

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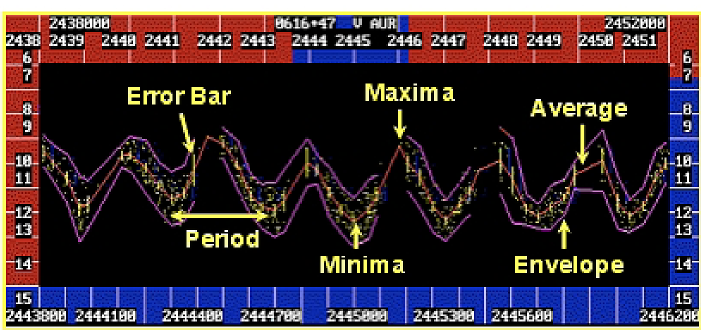



Figure 1. Grant Foster's original DOS-based VSTAR (provided by AAVSO).

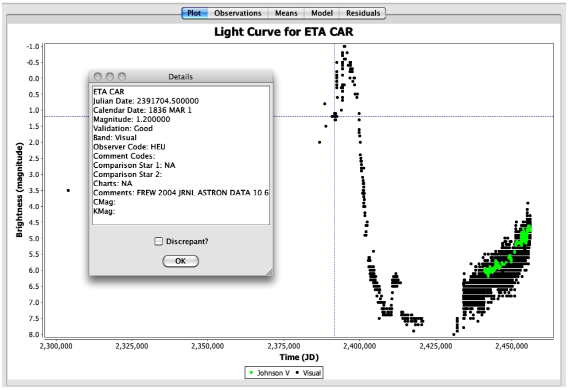
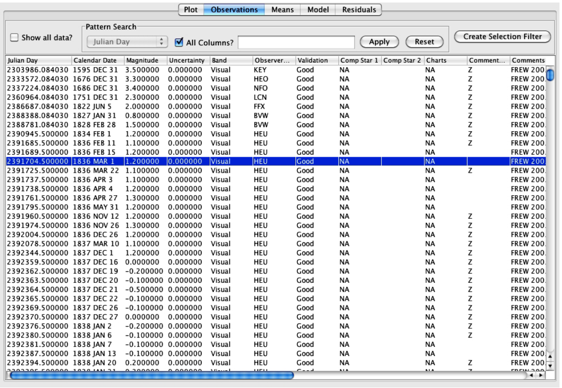



Figure 2. A plot of η Car, an observation selected in the cross-hairs, and a detail dialog.




| Julian Day | Calendar Date | Magnitude | Uncertainty | Band | Observer... | Validation | Comp Star 1 | Comp Star 2 | Charts | Comment... | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2303986.084030 | 1595 DEC 31 | 3.500000 | 0.000000 | Visual | KEY | Good | NA | | NA | Z | FREW 200 |
| 2333572.084030 | 1676 DEC 31 | 3.300000 | 0.000000 | Visual | HEO | Good | NA | | NA | Z | FREW 200 |
| 2337224.084030 | 1686 DEC 31 | 3.400000 | 0.000000 | Visual | NFO | Good | NA | | NA | Z | FREW 200 |
| 2360964.084030 | 1751 DEC 31 | 2.300000 | 0.000000 | Visual | LCN | Good | NA | | NA | Z | FREW 200 |
| 2386687.084030 | 1822 JUN 5 | 2.000000 | 0.000000 | Visual | FFX | Good | NA | | NA | Z | FREW 200 |
| 2388388.084030 | 1827 JAN 31 | 0.800000 | 0.000000 | Visual | BVW | Good | NA | | NA | Z | FREW 200 |
| 2388781.084030 | 1828 FEB 28 | 1.500000 | 0.000000 | Visual | BVW | Good | NA | | NA | Z | FREW 200 |
| 2390945.500000 | 1834 FEB 1 | 1.200000 | 0.000000 | Visual | HEU | Good | NA | | NA | Z | FREW 200 |
| 2391685.500000 | 1836 FEB 11 | 1.100000 | 0.000000 | Visual | HEU | Good | NA | | NA | Z | FREW 200 |
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| 2391960.500000 | 1836 NOV 12 | 1.200000 | 0.000000 | Visual | HEU | Good | NA | | NA | Z | FREW 200 |
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| 2392363.500000 | 1837 DEC 20 | -0.100000 | 0.000000 | Visual | HEU | Good | NA | | NA | Z | FREW 200 |
| 2392364.500000 | 1837 DEC 21 | -0.500000 | 0.000000 | Visual | HEU | Good | NA | | NA | Z | FREW 200 |
| 2392365.500000 | 1837 DEC 22 | -0.100000 | 0.000000 | Visual | HEU | Good | NA | | NA | Z | FREW 200 |
| 2392369.500000 | 1837 DEC 26 | -0.100000 | 0.000000 | Visual | HEU | Good | NA | | NA | Z | FREW 200 |
| 2392370.500000 | 1837 DEC 27 | 0.000000 | 0.000000 | Visual | HEU | Good | NA | | NA | Z | FREW 200 |
| 2392376.500000 | 1838 JAN 2 | -0.200000 | 0.000000 | Visual | HEU | Good | NA | | NA | Z | FREW 200 |
| 2392380.500000 | 1838 JAN 6 | -0.100000 | 0.000000 | Visual | HEU | Good | NA | | NA | Z | FREW 200 |
| 2392381.500000 | 1838 JAN 7 | -0.100000 | 0.000000 | Visual | HEU | Good | NA | | NA | | FREW 200 |
| 2392387.500000 | 1838 JAN 13 | -0.100000 | 0.000000 | Visual | HEU | Good | NA | | NA | | FREW 200 |
| 2392394.500000 | 1838 JAN 20 | 0.200000 | 0.000000 | Visual | HEU | Good | NA | | NA | Z | FREW 200 |

Figure 3. The tabular view of the η Car dataset shown in Figure 2 with the same observation row selected.

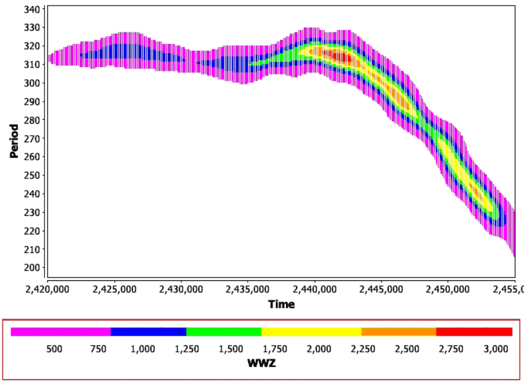


Figure 4. WWZ plot for T UMi showing period change over almost a century.

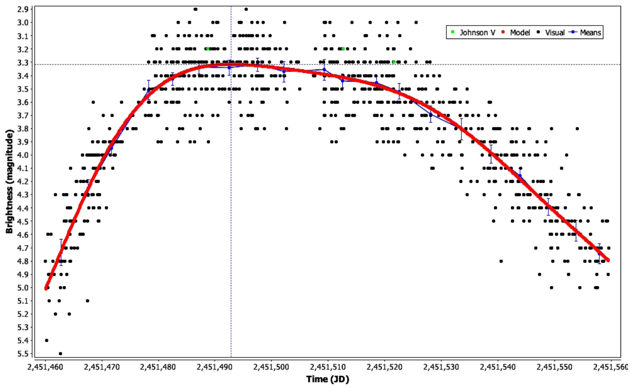


Figure 5. A polynomial fit of degree 7 for o Cet with 5-day binned means.

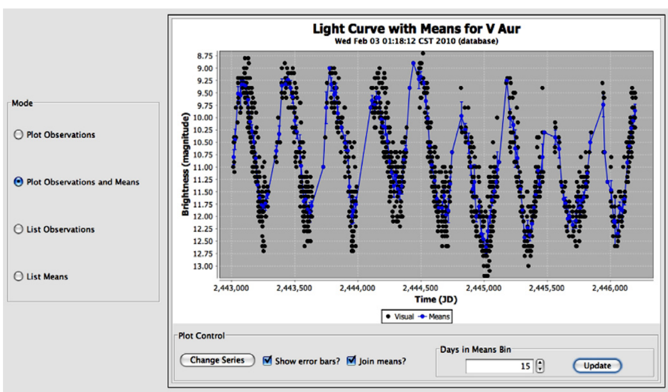


Figure 6. A screen-shot of VSTAR at the time of NACAA 2010.

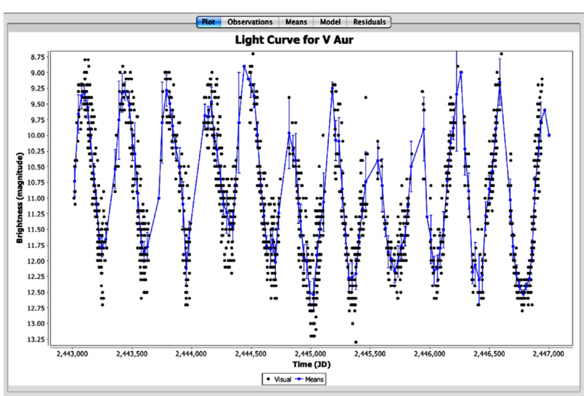


Figure 7. VSTAR's modified interface as it has become since NACAA 2010.

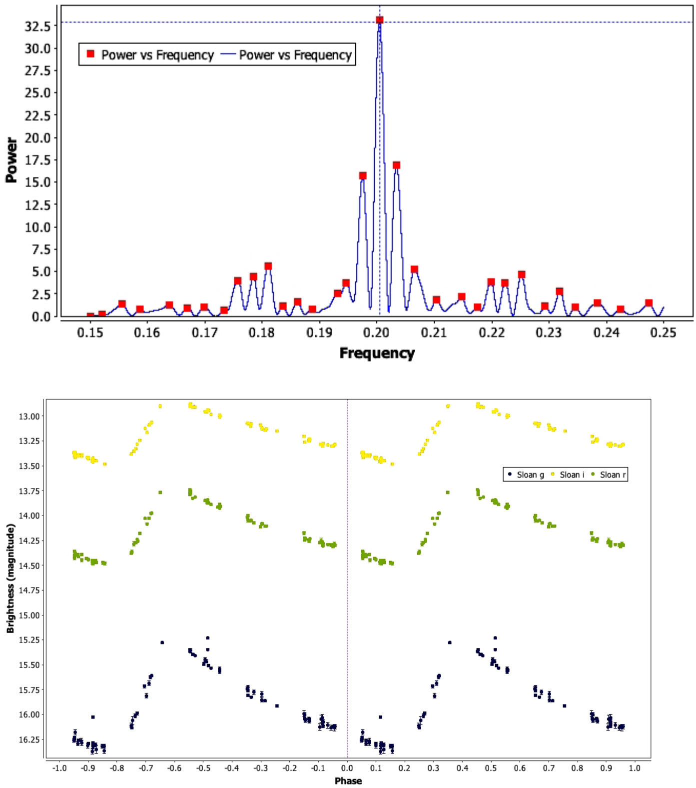


Figure 8. A VSTAR DCDFT power spectrum (upper panel) and phase plot (lower panel) resulting from top-hit period, for 2MAS J03145502+5618172.

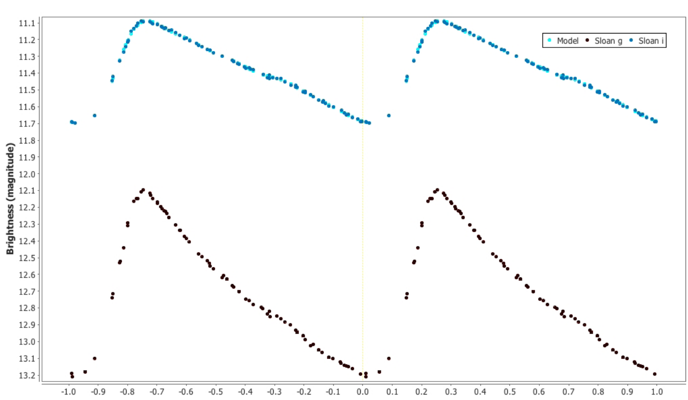


Figure 9. Phase plot for GV Aur resulting from DCDFT period analysis.