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Cleaning up the GCVS Eclipsing Binary Listings: Strategies and Tools to Maximize Success

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Abstract

While some may expend their efforts on surveys and discovery of new variable stars, many 'known' variable stars are poorly studied and little more than a one-line entry in a catalog, such as the General Catalog of Variable Stars (GCVS). In fact you will find many periodic variable stars in the GCVS that lack a period, epoch, or both. This is an area where the interested amateur can make scientific contributions. With background research and the right tools and strategies, observing time can be very productive when studying these 'little known' variable stars.

1. Introduction

The beginning photometrist must always face these questions: What stars should I observe? Will I see results in one or two nights? Do I need special filters? This paper proposes an observing project that has as its target list a subset of the GCVS eclipsing binary listings. With proper star selection and background research, the amateur is practically guaranteed to capture an eclipse on the first night or two. This project requires no special filters, which makes it ideally suited to the beginner and is an excellent topic for a high school science fair project.

2. The General Catalog of Variable Stars (GCVS) and Your Initial Target List

The General Catalog of Variable Stars (GCVS) is the starting point from which to generate a list of target stars that lack ephemeris data. Geert Hoogeveen has also done an excellent job of compiling a variable star catalog from other sources to supplement the GCVS listing. Importing these listings into a spreadsheet makes it easy to sort and filter them by right ascension, variable type, min and max magnitude, epoch, period, and so forth. As a beginner you may want to select only brighter, higher amplitude variables of these types: E, EA, EB, EW. The easiest is type EW because this family has such short periods. As you gain more experience and confidence you can take on more challenging stars.

3. Performing Background Research on Your Target Stars – Weeding out low Probability Candidates

The initial target list you've culled from the GCVS needs to be filtered by comparing it against data from other sources. This is important in order to select only those targets for which you can create a reasonably accurate ephemeris. With this ephemeris, you can predict when eclipses are likely to occur and maximize the productivity of your observing time. Without a good ephemeris, you can do no better than choose a random observing schedule, which can be very unproductive and unrewarding.

There are several sources of data you can research: online publications, archived publications (not accessible through the Internet), online photometric surveys, and online survey images.

Online publications include the Information Bulletin on Variable Stars (IBVS), the AAVSO Published Times of Minimum Database, Eclipsing Binaries Minima Database, Atlas of O-C Diagrams of Eclipsing Binary Stars, and many others. See the references at the end of this paper for a listing of online publications and variable star observing organizations. If all else fails there is the NASA ADS Astronomy Query Form, but don't forget to look up alternate names of your star in SIMBAD.

These various publications and organizations are largely a source of eclipse timings that help determine an accurate ephemeris.

Archived publications are not available on the Internet. This means you must travel to nearby observatory, university, or city libraries that have archives available for research. This availability is different for each person, but if the trip is not too long, it may provide valuable eclipse timing information from old epochs that help improve the accuracy of predictions for the current epoch. One other option is to collaborate with a friend that has easier access to archived publications. Such collaborations can be very rewarding.

Online surveys include the Northern Sky Variability Survey (NSVS), The All Sky Automated Survey (ASAS), Hipparcos data (text and graphic form), and The Amateur Sky Survey (TASS) MarkIV Engineering Run Database. Note that with Hipparcos data you need to search by Hipparcos catalog number. You can determine if a given star has a Hipparcos catalog number by cross-referencing in the GCVS, or using SIMBAD. Generally stars must be 10th magnitude or brighter to have a Hipparcos catalog number.

If you're lucky, you'll find that your 'unknown' GCVS target star has a Hipparcos catalog number and the Hipparcos team has been able to determine an unambiguous period and epoch. This information may be good enough for you to predict future eclipses and easily capture one. However, it may turn out that the Hipparcos team has not determined the period with enough precision, or that their period is an aliasing artifact. In both cases you will need data from other sources, if available, or additional observations on your part.

You'll soon learn that each online survey has different sky coverage and magnitude limits. Hipparcos covered the entire sky but only to about magnitude 10. NSVS covered the northern sky down to about magnitude 14. TASS currently covers the northern sky. ASAS currently covers the southern sky. Each online survey also has different data to provide. Hipparcos time data is already in heliocentric day format, but others are not and heliocentric time corrections must be applied for later analysis and period searches.

It's important to examine a survey image of each target star to determine two things. First, are the GCVS coordinates accurate? Second, is the star field crowded? This can be a factor in what online photometric data you can get and what quality it will be. The online photometric surveys (not Hipparcos) used wide field imaging systems with pixel sizes that made it difficult to resolve stars closer than about 1 arcminute. A quick look at a survey image will tell you if such a problem exists for your target star. If there is a close neighbor star, it means the photometric data may be a blend of the two stars. This means that photometric precision may suffer – you'll see more scatter in the measurements – and that any amplitude in the variable star will be smaller than the true value.

At this point you've collected all available data on your target stars. You may find that some stars have little additional data beyond the entry in the GCVS. These stars can be dropped off the list as low probability of success candidates. Some stars will have a small amount of data – perhaps one or two publications with a few eclipse timings – and maybe one online photometric survey that provides data. These stars can be considered medium probability of success candidates. Some stars will have a robust data set from online publications, archived publications, and more than one photometric survey. These stars can be considered high probability of success candidates. Let's continue to work with these high probability stars.

4. Making Sense of all Your Background Research.

You now have a collection of old eclipse timings and fairly recent photometric data for your high probability stars, and you need to analyze them to see if they provide a meaningful epoch and period.

First, did any published source provide a period? If yes, you can plot all eclipse timings on an O-C (observed minus calculated) chart. (We'll see an example of this later.) At a glance this will tell you if the period is reasonably accurate or not.

If no period is provided, you'll have to search for candidate periods. One tool for this is TomCat software, written by Bob Nelson. This software will analyze a list of eclipse timings over a range of periods and provide a graphic plot of how likely a given period is the correct solution. Keep in mind that if you only have a small number of eclipse timings it may be difficult or impossible to determine the correct period unambiguously. We'll assume that we've either had a reasonably accurate period provided, or that we've determined it with TomCat and a healthy number of eclipse timings.

Now we can analyze online photometric data and compare its results to older eclipse timings. Initially the photometric data looks like a random jumble because the time sampling is random and often at large time intervals. Periodic behavior is not evident.

If we have a reasonably accurate period from old eclipse timings, we can phase plot this data using this period. Don't forget to make the applicable heliocentric time corrections to this data, except for Hipparcos. Even a simple spreadsheet can be used to accomplish both tasks. If the period is unknown we'll have to search for likely candidates. Bob Nelson's software Period Search is well suited to this task.

You can search ranges of periods and examine a graphic output that shows the likelihood that any period has a strong periodic component. As you analyze candidate periods closely, you can call up a phase plot to see if you get a reasonable looking light curve that displays either a primary eclipse or both a primary and secondary eclipse.

As you analyze online photometric data for candidate periods, you may be surprised to see phase plots that have three or more eclipse events. Is this a rare triple eclipsing system? No, it's an aliasing artifact. With a small amount of sparsely sampled photometric data there may be more than one candidate period that looks good to period analysis software. This is where human judgment comes in when looking at phase plots. In some cases, especially with very short period systems that have essentially identical primary and secondary eclipses, it may be very difficult to judge the best candidate period. Often one long observing run can help answer this question for short period systems.

Now that you've determined the most likely period from online photometric data, it's important to also derive an eclipse timing from the data. A spreadsheet can be used to extract this, and I'll gladly email copies of what I've developed for this purpose.

In the final stage of analysis you compare all data sources. Do old eclipse timings indicate a certain period? Do they agree with the most likely period and phase plot from online photometric data? Does the eclipse timing from online photometric data show a significant change in the O-C plot? Will you have to use a slightly different period to make predictions for the current epoch?

If all your data sources support one another and point to an unambiguous period and epoch, you know that you've selected a star with a high probability of success. Generate a list of predictions for the current observing season so that you can make a schedule. You'll find that some periods may appear to be relatively short, but the opportunities they offer to catch an eclipse may come only a few times a season. If you are working on a number of target stars, it's helpful to assign a high priority to those that have few observing opportunities each season.

5. WW Lyncis – One Example

One star in the GCVS with no listed period or ephemeris is WW Lyn, which is fairly bright at around 12th magnitude. The GCVS references one article (Kinman 1982), and a quick look at that article appeared to indicate the case was closed – period, epoch, and light curve were all there. This paper labels the star as RR-VI-37. See page 322 for a finder chart. To be thorough I decide to compare those results with online photometric data.

This star was too faint for Hipparcos and too far north for ASAS. A quick query of NSVS data and a phase plot showed a disparity. The light curve did not appear to support that paper's period.

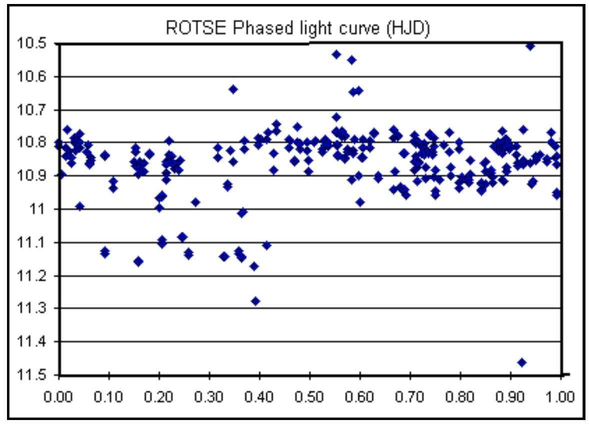

Figure 1. WW Lyn phase plot for a period of 1.208 days.

Converting the NSVS data to HJD and analyzing it in Period Search, there were several aliased candidate periods. However the phase plot at a period near 5.812 days looked the most promising.

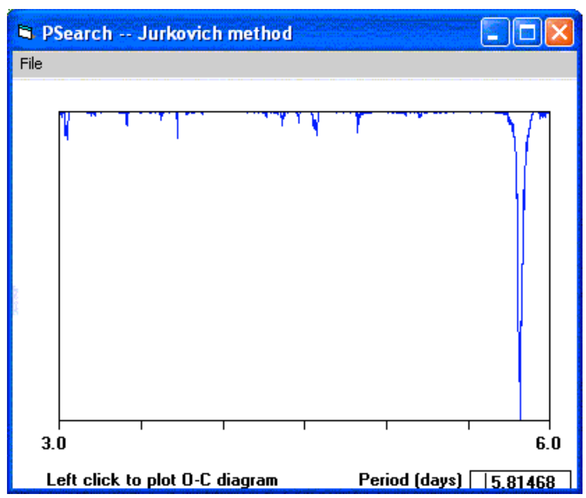

Figure 2. WW Lyn output from Period Search showing likely period near 5.81 days.

Using that period, an epoch from the middle of all NSVS data was extracted. (Note: Kinman's period of 1.208 days is an alias of 5.812.)

The next step was to compare the eclipse timings from Kinman's paper in an O-C plot, using the period and epoch from NSVS data. Another disparity showed up. Kinman's timings largely plotted on a straight, horizontal line, but at a considerable offset from the NSVS data.

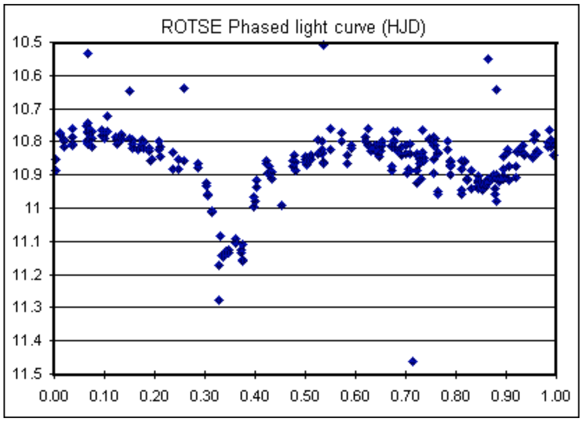

Figure 3. WW Lyn phase plot for a period of 5.812 days.

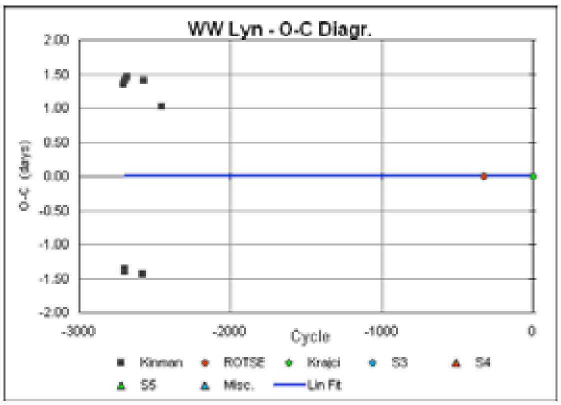

Figure 4. O-C plot using Kinman's timings (no phase correction applied).

A little head scratching showed that Kinman's timings were all offset by ¼ of the NSVS period. Because Kinman's period was an alias of the NSVS period, and his timings were off by a simple fraction of the period, I applied this correction to Kinman's timings. (Sometimes aliased signals have an associated phase shift.) With O-C plots lining up well I felt reasonably confident that I could predict and capture an eclipse of this star.

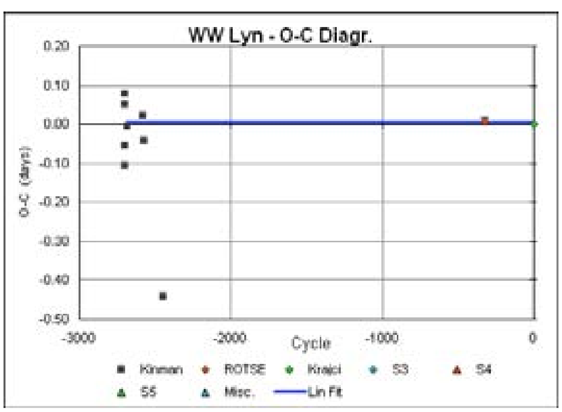

Figure 5. O-C plot using Kinman's timings (phase correction applied).

A period of 5.812 days meant that I had a good observing window only about once a month. Eventually weather cooperated and I was in fact able to capture an eclipse of this star, as predicted with this period.

The moral to the story is there can be errors in published values. Cross-checking between multiple sources is an essential part in finding and eliminating these errors.

6. Some Additional Comments

The process I've outlined above appears linear, but it may become iterative, especially when you are researching stars with sparser data sets that initially appear conflicting. This paper can serve as a starting point for the beginning photometrist, and experience will guide you in how to better select target stars.

Serendipity is its own reward. Discoveries of new variable stars will happen as you work more target stars. If you photometrically data mine all stars in your field, or just use several comparison stars and eventually find that one of your comp's is not constant, eventually you'll make a discovery.

Sometimes your target star is not an eclipsing binary, but an RR Lyr instead. This will be apparent when the descending leg to minimum light has a shallower slope than the ascending leg coming out of minimum light.

Or your target star may be an eclipsing binary, but the period appears to be changing and, perhaps, in unusual ways. This may be a star worthy of longer-term study.

In your first attempts you may not want to choose stars for which epoch and period are unknown. You may want to choose stars for which the period is known (perhaps to low precision) but that have not been observed for several or more years. A good source of such stars is the Rolling Hills Observatory Eclipsing Binary Ephemeris Generator http://www.rollinghillsobs.org/perl/calcEBephem.pl. It provides eclipsing binary predictions for a user-defined geographic location. It also lists how many orbital cycles since the epoch of last observation recorded in the database. There are many GCVS stars with periods and epochs that have not been observed in years or decades.

7. Conclusion

Many known variable stars are in need of greater study. Many are lacking even basic data in the GCVS. Dedicated observations by interested amateurs and students can make substantial contributions to improving our knowledge of variable stars. Background research of all available data identifies stars that can be easily solved with only one or two night's new data.

Along the way you can make unexpected and surprising discoveries, establish professional and amateur collaborations across the globe, and find inspiration in exploring and solving some of the mysteries of the heavens.

8. Acknowledgements

I'd like to thank the AAVSO Eclipsing Binary work group for their mentoring and support. http://www.aavso.org/observing/programs/eclipser/

9. References

Kholopov, P.N., Samus, N.N., Frolov, M.S., Goranskij, V.P., Gorynya, N.A., Kireeva, N.N., Kukarkina, N.P., Kurochkin, N.E., Medvedeva, G.I., Perova, N.B., and Shugarov, S.Yu. 1985-88, General Catalogue of Variable Stars, 4th edition, Volumes I-III, (Moscow, Nauka Publishing House) ftp://ftp.sai.msu.su/pub/groups/cluster/gcvs/gcvs/iii

Hoogeveen, Geert, Catalogue of variable stars http://www.xs4all.nl/~gertho/Catalogue.htm

Northern Sky Variability Survey (NSVS, aka ROTSE) http://skydot.lanl.gov/nsvs/nsvs.php

The All Sky Automated Survey (ASAS) http://archive.princeton.edu/~asas/

Hipparcos data (text) http://www.rssd.esa.int/hipparcos_scripts/HIPcatalogueSearch.pl?hipepId=1

Hipparcos data (graphic) http://www.rssd.esa.int/Hipparcos/apps/PlotCurve.html

TASS (The Amateur Sky Survey) MarkIV Engineering Run Database http://sallman.tass-survey.org/servlet/markiv/template/DataDownload.vm;jsessionid=2AA08D14B42E894700FA2A8B7D4632FC

ECLIPSING BINARIES OBSERVING PLAN (Sebastian Otero)
http://ar.geocities.com/varsao/EA_observations.htm
http://ar.geocities.com/varsao/eclipsing_binaries_observing_plan.htm

INFORMATION BULLETIN on VARIABLE STARS http://www.konkoly.hu/IBVS/IBVS.html

AAVSO Published Times of Minimum Database http://www.aavso.org/observing/programs/eclipser/ebtom.shtml

Bob Nelson's O - C Files, http://www.aavso.org/observing/programs/eb/omc/nelson_omc.shtml

Eclipsing Binaries Minima Database http://www.oa.uj.edu.pl/ktt/

Atlas of O-C Diagrams of Eclipsing Binary Stars http://www.as.ap.krakow.pl/o-c/index.php3

Smithsonian/NASA ADS Astronomy Query Form http://adsabs.harvard.edu/abstract_service.html

Bundesdeutsche Arbeitsgemeinschaft für Veränderliche Sterne e.V. (BAV) http://www.bav-astro.de/index_e.html

Mitteilungen über Veränderliche Sterne (MVS) http://www.stw.tu-ilmenau.de/science/pub/MVS/content.html

Swiss Astronomical Society Bulletins (BBSAG) http://www.astronomie.info/calsky/

Association Française des Observateurs d'Étoiles Variables (AFOEV) http://cdsweb.u-strasbg.fr/afoev/

British Astronomical Association Variable Star Section (BAAVSS) http://www.britastro.org/vss/

SIMBAD http://simbad.u-strasbg.fr/sim-fid.pl

Rolling Hills Observatory Eclipsing Binary Ephemeris Generator http://www.rollinghillsobs.org/perl/calcEBephem.pl

Kinman, T. D.; Mahaffey, C. T.; Wirtanen, C. A. An RR Lyrae survey with the Lick astrograph. V - A survey of three fields at intermediate latitudes towards the galactic anticenter. http://adsabs.harvard.edu/cgi-bin/nph-bib_query?bibcode=1982AJ.....87..314K&db_key=AST&data_type=HTML&format=&high=4152f330d822360