

CONTRIBUTING TO SCIENCE WITH YOUR CCD EQUIPMENT

Contributing To Science With Your CCD Equipment Article by Tim Crawford

Increasingly CCD equipment is becoming a common accessory for amateur observers. Most folks purchase the equipment because of the stimulation that the astro photo's of others creates and the desire to create their own. I came to the conclusion early on with my own CCD equipment that others did a much better job of creating those astrophoto masterpieces than I could and initiated search for an activity that would allow me to make a contribution to science. Other folks mastered astro imaging and created many masterpieces but after a few years seemed to run out of interesting targets and places to hang their work. They also initiated a search for an activity that would allow them to make a scientific contribution.

Most of us eventually ended up on the door step of the American Association of Variable Star Observers (AAVSO) with the lure that we could all make useful scientific contributions with our CCD equipment by imaging selected variable star fields and then performing photometry (measuring the magnitude) of the selected variable star. (Visual observers are also welcome):

www.aavso.org

Just yesterday I received the AAVSO Special Notice #113 which had a request from Benjamin Beeck and Dr. Sonja Schuh (IfA, Goettingen) requesting that members of the AAVSO do time series observations (multiple images) of a close binary star VSX J212531.9-010745 in support of a study they are doing on this variable star system. The previous AAVSO Special Notice #112 was a request from Dr. Margarita Karovska (Harvard-Smithsonian CfA) requesting intensive observations of the symbiotic star CH Cyg in support of observations that the Hubble Space Telescope and the orbiting Chandra X-Ray observatory were undertaking (both visual and CCD). Prior to that Special Notice was #111 requesting observations of a possible super outburst of DH Aql, a SU UMa type dwarf nova, in support of the Spitzer space telescope. Recent Alert Notices included #379 with a request from Dr. Steve Howell (NOAO) to monitor suspected tremendous outburst amplitude dwarf novae (a list of 20 individual stars) in support of the Spitzer space telescope; #378 with a request from Dr. Paula Szkody (University of Washington) to monitor the cataclysmic variable RE J1255+266 in support of the Hubble space telescope.

Well, ok, I think you are getting the idea that the professionals make a fair number of requests of AAVSO observers, the majority of whom are simply amateurs like you and me, for observations of specific variable stars. In fact, as I write this, the AAVSO has nine open Campaigns (requests for observations to achieve specific goals), mostly representing requests from the professional community, covering some 36 individual variable stars and one Exoplanet:

www.aavso.org/news/campaigns.shtml

Then of course there are the ~ two hundred stars on the current listing of the AAVSO data base variable stars in need of more observations:

Figure. 1. VSP entry screen for chart generating

The screenshot shows the 'AAVSO Variable Star Plotter' web form. It includes fields for 'Location*' (Name: AM Her, RA, Dec), 'Title', 'Comment', 'Plot a chart of this scale:' (set to 'F'), 'FOV*' (18.5), 'Resolution*' (100), 'Mag. Limit*' (18.5), 'North' (Up/Down), 'East' (Right/Left), 'Image' (Use DSS image), 'Field Photometry' (Do not plot a chart, just give me a table of photometry), 'Other Variables' (Do not mark additional variables in the field, Mark GCVS variables in the field of view, Mark all variables in the field of view), and 'Chart ID'. There are 'Reset Fields' and 'Plot Chart' buttons at the bottom.

In addition there are ~ 5,000 variable stars in the AAVSO data base that have available charts with known comparison stars, many of which are under observed; oh, and there are more lists of specific types of variable stars that individual professionals have created web sites for with the request that the data be reported to the AAVSO.

Doing variable star observing and reporting of data to the AAVSO lets amateur astronomers make a real contribution to science and allows all of us an opportunity to be an active participant in observing campaigns initiated by the professional community.

Photometry (measurement of a target stars magnitude) is really relatively simple with today's hardware and software. For those of you who own CCD equipment the only other two components you really need is software that will do the photometry analysis for you (and some of you may already own such software for your imaging and image manipulation) and, preferably, a "V" filter.

Whether using a CCD or doing visual observations the photometry is accomplished by comparing stars of a known magnitude to the variable star (target) whose magnitude you are trying to measure. The AAVSO makes this a relatively easy process with their Variable Star Plotter (VSP):

www.aavso.org/observing/charts/vsp/

I will now take you through the steps of downloading a chart and then using that chart to image a specific variable star and by using the chart data to then measure the magnitude of the variable star, with the aid of software, and then to upload that information to the AAVSO data base.

AM Her is a cataclysmic variable (binary star systems

that have occasional violent outbursts) and specifically AM Her belongs to a subclass called "Polars." Polars have very strong magnetic fields and emit most of their energy as X-Rays.

Figure 1, below, shows the VSP entry screen (previous link) that we will use to select the correct scale (size of the field of view-FOV) as well as the correct orientation (i.e., North up or North down).

Figure 2 shows the chart created by the VSP for the AM Her FOV that I selected; this "F" scale chart has a FOV of ~ 18.5 arc min which is a reasonable choice for the ~ 11.7 x 11.7 arcmin image scale produced with my SBIG ST-9XE CCD and a 12" SCT at f/10.

As I do not use the diagonal with my SCT, when using the CCD, I have only two reflections (mirrors) and therefore use a chart with North down to match my image (CCD with "plugs" up); if I were also using the diagonal with the CCD which would give me three reflections (mirrors) that would require a chart with North up. Whatever your setup, it will only take a few images to insure you have the correct chart orientation selected.

The Chart shown in **figure 2** shows the magnitudes (three digits) of the comparison stars (measured known values of stars that do not vary, hopefully). The 122 value really means a magnitude of 12.2; the periods are not used least an observer mistake the period for a star. These values are also intended for visual observers as CCD observers can achieve measurements to three decimals while most visual observers can only achieve measurements to one decimal.

To locate the magnitudes of the comp stars to three digits you select the "Comparison Stars" link which will show at the top of the chart page generated by the VSP or you can select from the VSP page to only generate the table. Figure 3 shows an abbreviated copy of the table of photometry for

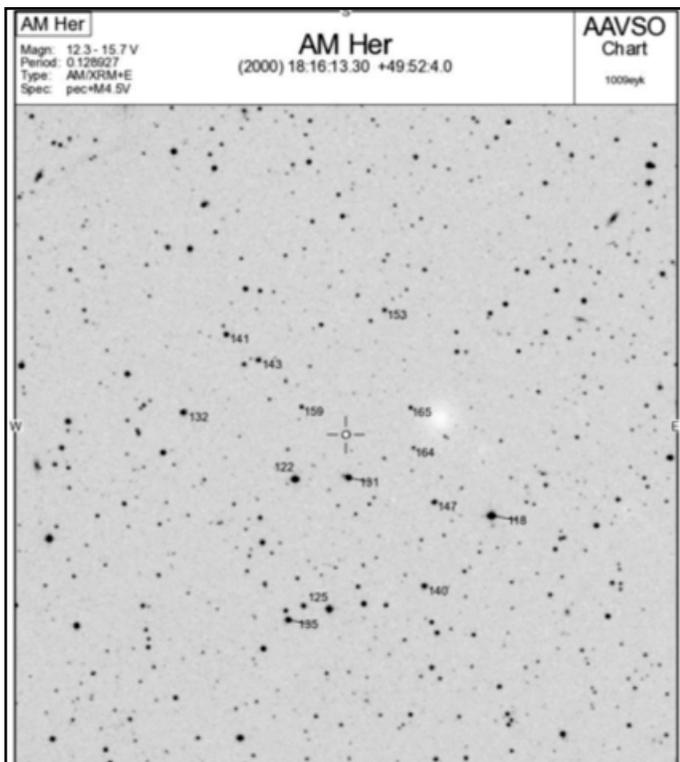


Figure 2. (left) Chart generated from VSP screen-Fig 1. AM Her is the circle with the 4 radii

Figure 3. (Below) AM Her table of photometry showing comparison star data to three digits for CCD's.

AUID	RA.	Dec.	Label	U	B	V
000-BCB-827	18:16:38.45 [274.16022d]	49:54:20 [49.90556d]	118	-	12.693 (0.015) ¹⁰	11.765 (0.014) ¹⁰
000-BCB-795	18:16:04.40 [274.01834d]	49:53:19 [49.88861d]	122	-	12.787 (0.015) ¹⁰	12.198 (0.013) ¹⁰
000-BCB-800	18:16:10.30 [274.04291d]	49:56:56.8 [49.94911d]	125	-	12.959 (0.016) ¹⁰	12.457 (0.013) ¹⁰
000-BCB-803	18:16:13.52 [274.05634d]	49:53:15.8 [49.88772d]	131	-	13.760 (0.022) ¹⁰	13.109 (0.020) ¹⁰
000-BCB-778	18:15:45.04 [273.93765d]	49:51:26 [49.85722d]	132	-	13.583 (0.017) ¹⁰	13.192 (0.015) ¹⁰
000-BCB-793	18:16:03.12 [274.01300d]	49:57:14.3 [49.95397d]	135	-	14.501 (0.017) ¹⁰	13.465 (0.014) ¹⁰
000-BCB-818	18:16:26.77 [274.11154d]	49:56:18.2 [49.93839d]	140	-	14.808 (0.018) ¹⁰	13.966 (0.013) ¹⁰
000-BCB-785	18:15:52.43 [273.96844d]	49:49:15.5 [49.82097d]	141	-	14.741 (0.021) ¹⁰	14.075 (0.014) ¹⁰
000-BCB-790	18:15:58.02 [273.99176d]	49:49:58.2 [49.83283d]	143	-	14.908 (0.025) ¹⁰	14.312 (0.022) ¹⁰
000-BCB-820	18:16:28.51 [274.11880d]	49:53:56.7 [49.89908d]	147	-	15.372 (0.036) ¹⁰	14.718 (0.030) ¹⁰
000-BCB-809	18:16:19.84 [274.08267d]	49:48:34.8 [49.80967d]	153	-	16.261 (0.020) ¹⁰	15.314 (0.014) ¹⁰
000-BCB-796	18:16:05.51 [274.02295d]	49:51:17.1 [49.85475d]	159	-	16.436 (0.025) ¹⁰	15.893 (0.019) ¹⁰
000-BCB-814	18:16:24.87 [274.10364d]	49:52:26.2 [49.87394d]	164	-	17.176 (0.030) ¹⁰	16.449 (0.014) ¹⁰
000-BCB-813	18:16:24.26 [274.10107d]	49:51:18.6 [49.85517d]	165	-	17.518 (0.066) ¹⁰	16.481 (0.024) ¹⁰

Report this sequence as: 1009ceq in the chart field of your observation report.

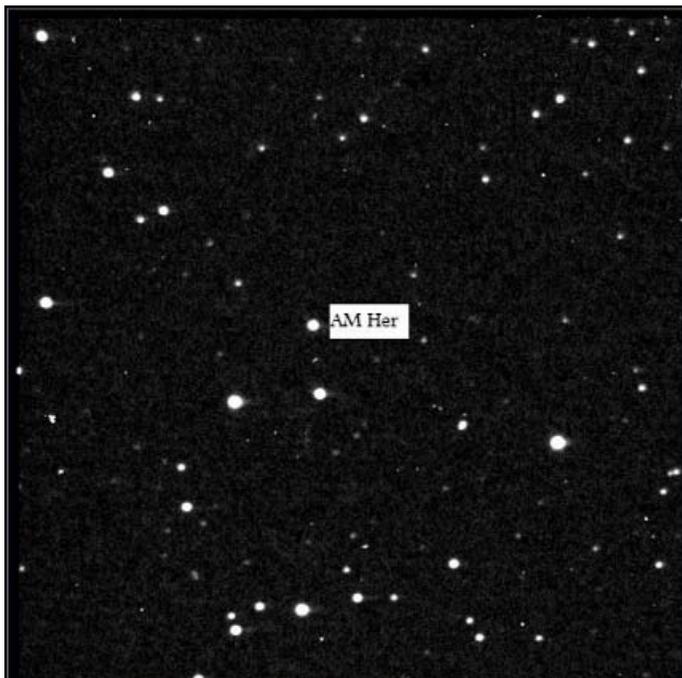


Figure 4. “V” filter CCD image of the AM Her FOV with AM Her marked

the AM Her FOV chosen (I omitted data for all but the B & V filters); the table lists the comparison star data to three digits.

To get a larger image of these first three figures I would urge you to go online where you can see these images in full scale, by following the links.

Now that I have a chart with the required FOV and the comparison star CCD information that will let me measure the magnitude, with software, I am now ready to image the AM Her (see figure 4) FOV with a “V” filter.

Now that I have an image I am ready to open my photometry program. In my case I use an Astronomical Image processing program called AIP4WIN V2:

www.willbell.com/aip/index.htm

This software comes with the book “Handbook of Astronomical Image Processing” by Richard Berry and Jim Burnell.

The first step is to calibrate the image (subtract darks and flats) then open the “Single Image Processing” (SIP) tool under the “Measure” tab.

Ideally, we want to use comparison stars whose magnitudes are close to the variable star we are measuring. When I look at my image (Figure 4) and the AM Her chart (Figure 2, which I suggest you print from online) it looks to my eye like AM Her is a bit dimmer than the 131 (13.1 magnitude) star directly to the North but a bit brighter than the 140 star to the NE so those are the two stars I will choose to let the software compute the magnitude. 131 will be the comparison star (comp) and 140 will be the check star that we will use to make sure that 131 is not varying in magnitude.

The “Single Image Photometry” (SIP) tool lets me place the mouse cursor on the variable star and after left clicking

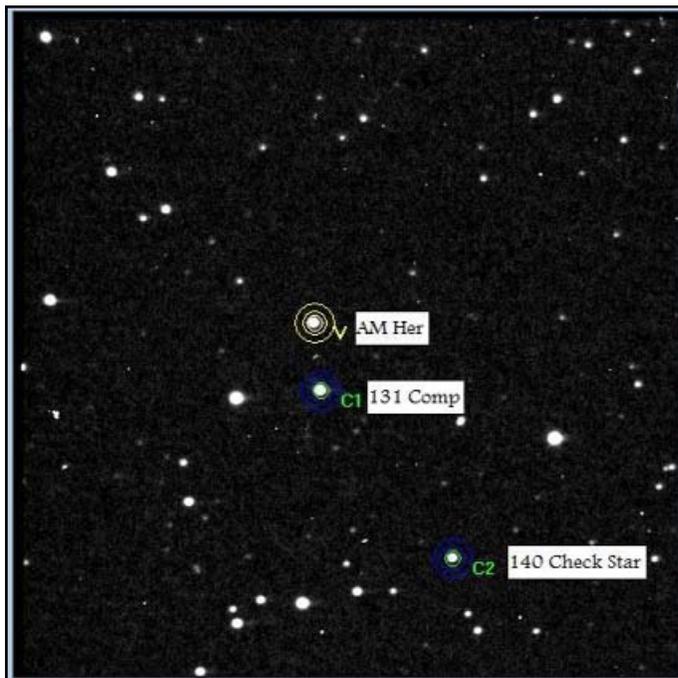


Figure 5. CCD image of the AM Her FOV showing the selected comparison and check stars.

the software then circles AM Her with an aperture and two annulus rings and marks it with a “V.” Then I click on the 131 star and it will also be circled with rings but marked C1 (this will be our comp star) and the last step is to click on the 140 star and it will be marked C2 (this will be our check star)-See Fig 5 where I have labeled the stars.

After these steps are done click on the “Get Magnitude” bar of the SIP tool and a data log will be created showing what we call the instrumental magnitudes of the three circled stars. Instrumental magnitudes should be viewed as “arbitrary” numbers in that while their relative relationships are meaningful the individual instrumental magnitudes are not the actual magnitudes.

As an example, from the following data taken from the data log (table 1), notice that the listed instrumental magnitude for the comparison star 131 (C1) is listed at 13.794; when we look at the comparison star data (figure 3)) we note that the “V” filter magnitude for the 131 star is actually 13.109. Obviously this figure is not equal to the measured instrumental magnitude but the difference between the Variable and C1 instrumental magnitudes is .238 magnitudes (14.032-13.794) and this relationship is very meaningful in that the actual magnitudes of both of these stars have a difference of .238 magnitudes (hence the name, Differential Photometry) and by using that difference we can compute the actual magnitude of the variable (AM Her).

Star	Instrumental Mag	±Sigma
Var	14.032	0.0028
C1	13.794	0.0024
C2	14.642	0.0041

Table 1. Taken from the AIP program data log and shows the measured instrumental magnitudes and uncertainty/error

Figure 6. AAVSO form for reporting individual observations

(Sigma).

$$V = C + (v-c)$$

Where: V = Variable Magnitude
 C = Comp "Chart" Magnitude
 v = Variable Instrumental Mag
 c = Comp Instrumental Mag

In this case then:

$$V = 13.109 + (14.032-13.794)$$

$$V = 13.109 + .238$$

$$V = 13.347$$

Actually, AIP4WIN will allow you to adjust the instrumental "zero point" (within the settings tab) such that the comparison stars magnitude value = the instrumental magnitude which enables direct reading of the actual magnitude of the variable without having to use the formula but it is important for the reader to understand the above process.

Now, we have one more task and that is to examine the check star data and insure that the comp star is not "significantly varying on us. If you look at the data in Figure 3 (and I hope you printed out the table from online) you will note that the actual "V" filter magnitude difference between the comp star labeled 131 and the check star labeled 140 is .857 magnitudes (13.966-13.109). Now compute the instrumental magnitude difference between these two same stars (comp & check): 14.642-13.794 = .848 which is a difference of .009 magnitudes with the known comp value differences. This is a good number and gives us confidence that we have chosen both a good comp star and a good check star. Depending upon the FOV, I am usually comfortable with an instrumental magnitude difference of up to .05 between the comp and check stars before I would go back and start selecting a different comp and or check star.

The Sigma value shown is a sophisticated measurement of the uncertainty (error) of the individual instrumental magnitudes.

I hope the above does not intimidate you because it is not really that complicated, in spite of possibly reading that way. Once you have actually taken the steps to do this you will realize that it is a relatively simple process that does not consume much time to accomplish.

I assume by now that if you have visited any of the AAVSO web sites you have come to realize that you do not need to be a member of the AAVSO to have access to most resources (although membership is always encouraged) nor

is it necessary to become a member to report observations. However, you will have to be issued observer initials to submit observations. This easy process that can be accomplished by visiting

www.aavso.org/bluegold/request_initials.php

and filling out the request form. Once you are emailed your initials you will be able to begin making reports.

www.aavso.org/bluegold/

Now, using our data log and the calculated magnitude for AM Her we are ready to fill out the data entry form shown in **figure 6**. The date I entered here is in Universal Time format, which is how the CCD recorded it and AIP4WIN output it to the data log. The Star Mag is the previously calculated 13.347. The error entered was

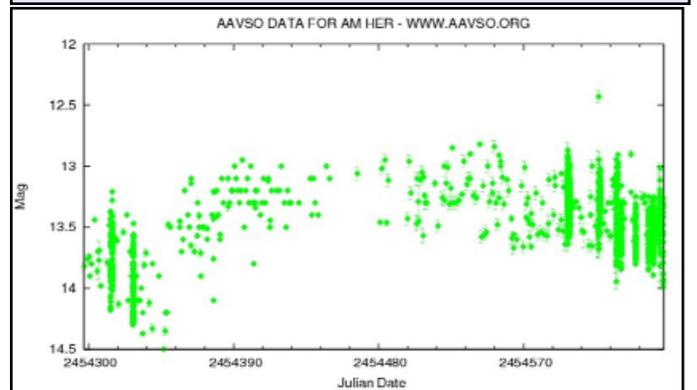
Figure 6. AAVSO form for reporting individual observations taken from the (v-c1) error calculation on the data log. The mag type selected is "ABS." Select "No" for Transformed and in this case I chose the Johnson "V" for the filter option. For the comp label you can use either the 131 chart notation or the unique identifier (AUID) found on the photometry table shown in figure 3 (000-BCB-803; recommended). The comp and check star magnitudes are the instrumental magnitudes from the data log. Select CCD and don't worry about air mass at this point. The Chart identifier is "1009chn" which is listed at the bottom of the photometry table (fig. 3-although not shown). After filling out the form you simply click the "Submit Observation to AAVSO Data Base" and you are finished.

Figure 7 Shows the one year light curve for AM Her, from observations submitted to the AAVSO, including this observation, using the AAVSO light curve generator.

www.aavso.org/data/lcg/

Speaking of light curves, you can create some really interesting ones with your own observations (or the observations of others). Figure 8 shows a string of observations I made over several hours, a few years ago, of an eclipsing binary system, DV UMa. Note that you can clearly see in the light curve when DV UMa was eclipsed by its companion on two different occasions throughout the observation run.

Figure 7. One year light curve for AM He



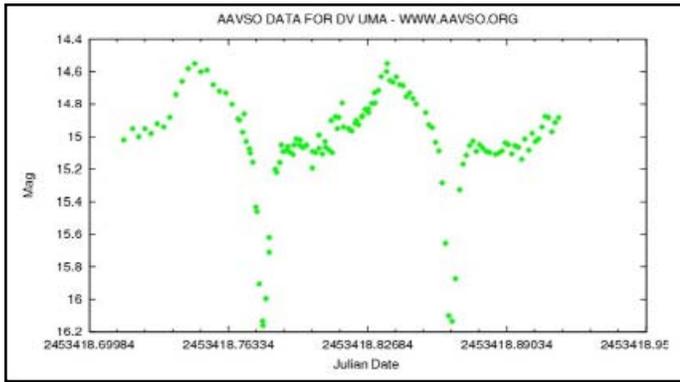


Figure 8. Light curve of DV UMa, an eclipsing binary system

The AAVSO has a wealth of information available for observers at all skill and learning levels. One of the best places to begin your new journey of discovery is the new member's page:

www.aavso.org/aavso/about/mentor.shtml

Be sure and click on the CCD observing manual link and download a copy. Also, don't be bashful about requesting a mentor to help you through the process.

Another good option is to join the two main AAVSO email discussion groups (general and photometry) and sign up for the alert notices:

www.aavso.org/publications/email/

If you need a quick answer to a question you can usually find help from someone signed into the AAVSO 24/7 online chat forum:

www.aavso.org/aavso/chat.shtml

A "V" filter source:

<http://www.astrodon.com/products/filters/photometric/>

There are simply not enough intuitional instruments to cover all the data needs of the professional astronomers and astrophysicists so the amateur community plays an important role in the gathering of photometry data for them. You can very readily be a part of that data gathering and make your own scientific contributions. The AAVSO and its observers and members have a lot of help to offer in support of your learning process.

Remember, there is no such thing as a dumb question!

Maybe, just maybe, if you get lucky you might even be the first to see the light of a new supernova and if not the first you can easily be one of the first to image one and report it's "current" magnitude. You will discover that once you become an active observer that you will have many opportunities to be among the first to catch many types of stars going into outburst.

On the door of my observatory I have posted a poem by Elizabeth Akers Allen:

"Backward,
Turn Backward,
O Time In Your Flight!
Make Me a Child Again,
Just For Tonight"

Oh, for the delight and excitement of new discoveries and adventures.

Ad Astra, Tim Crawford
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