Wheat and Chaff in the AID

11 February 2022
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Table of Contents

Introduction

In conversations about data quality[1] at AAVSO, I have encountered pushback from different points of view:

1. There is no such thing as photometric "truth."
2. Our data are fine as they are.
3. Our data have significant problems, but we lack the means to address those problems.
4. Our data have significant problems, but we can't address those problems without alienating our observers.[2]
5. Our data problems are insoluble.

I am of the opinion that there *are* significant problems, that we can and should takes steps to mitigate them, and that a failure to address the problems will marginalize our organization. I am told that in the Harvard CAP survey of professional astronomers, some respondents expressed the following attitude towards AAVSO: *Why should I waste my time with low-quality data?*

Although current headquarters staff can help scientists separate good data from bad, I doubt that there exists anything like comprehensive documentation of the types of problems that are found in the AID, the criteria for diagnosing those problems, or of the relative reliability of the various observers. After the current generation of staff retires or moves on the institutional memory will be lost, and future researchers will be left without guidance to evaluate our photometric legacy. As I lay out in the next section, astronomers will have other sources for light curves; they may not bother with data gathered without quality control.

Regarding the roots of poor photometry, Arne Henden remarked (of Nova Delphinus 2013): *It is not equipment, as Ulisse Munari's ANS consortium in Italy can achieve 0.012 mag total uncertainty between multiple observers, using amateur telescopes and CCDs. I think the difference is in technique*.[3]

I am sometimes painted as expecting everyone at AAVSO to practice "precision" photometry. That is not the case, and what you will find here are observers cutting corners and making outright mistakes. I have tried to illustrate a large variety of different anomalies, as opposed to many examples of particular problems. As appendicies, I include DSLR and CCD data quality reports I prepared for the Council in 2017. The identities of all the observers have been changed.

Thanks to Brian Skiff of Lowell Observatory for providing helpful insights.

1 CCD, DSLR, and PEP.
2 This is sometimes expressed as: *We never enforced quality standards before, so we can't start now*.
3 Emphasis mine.

The Competition

Variable star astronomy is being revolutionized by automated survey systems. In particular, AAVSO should be watching EvryScope, which operates in the heart of our present parameter space.

EvryScope uses multiple camera/telescope units on a single platform to achieve high sky coverage. By operating all night, it gathers photometry of the whole nighttime sky visible from a single location. EvryScope is described in 2015PASP..127..234L[4], and to quote from the abstract, the system will generate *1%-precision, many-year-length, high-cadence light curves for* <u>*every accessible star*</u> *brighter than ∼ 16th magnitude* (emphasis mine).[5]

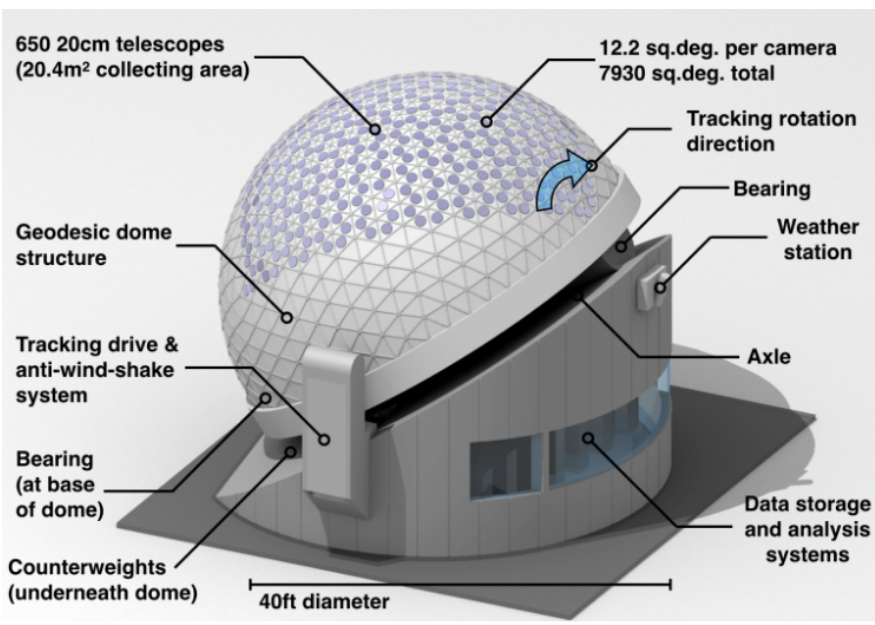
EvryScope website at https://evryscope.astro.unc.edu

Hardware	
System design	27 individual telescopes; shared equatorial mount
Telescope apertures	61 mm
Telescope mounting	Fibreglass dome w. aluminium supports
Detectors	28.8 MPix KAI29050 interline-transfer CCDs 7e- readout noise @ 4s readout time 50% QE @ 500 nm; 20,000 e- capacity w. anti-blooming
Field of view	380 sq. deg. per telescope (23.8° × 16.0°) 10,200 sq.deg. instantaneous total 8660 sq. deg. excluding overlap regions
Sky coverage per night	18,400 sq. deg. (2–10 hr per night)
Total detector size	780 MPix
Sampling	13.3″/pixel
Observing strategy	Track for 2 hr; reset and repeat
Data storage	All data recorded for long-term analysis 100 TB/year (compressed)

4 https://iopscience.iop.org/article/10.1086/680521/pdf
5 A slight exaggeration–the system appears to saturate at about V=6 in its normal operating mode.

Performance	
PSF 50% enclosed-energy diameter	2 pixels in central 2/3 of FoV; 2–4 pixels in outer 1/3
Exposure times	120s standard (plus shorter for bright-star mode)
Survey efficiency	97% efficiency from 4s camera readout
Limiting magnitude	$m_V = 16.4$ (3-sigma; 120s exposure)
	$m_V = 18.2$ (3-sigma; 1 hour)
	$m_V = 19.0$ (3-sigma, 1 night)
Photometric performance	1% photometry on $m_V < 12$ stars every 2 minutes (inc. scintillation)
	3-millimag photometry on $m_V = 11.5$ stars every 20 minutes
	3-millimag on $m_V = 6$ stars in 10 minutes (saturation-limited short exps.)
	1% photometry on $m_V = 15$ stars every hour

There are now two operational EvryScope stations, one in each hemisphere.[6] The project has been so successful that NSF is funding development of a scaled-up system called Argus that uses modest-size telescopes in place of telephoto lenses. A prototype system is scheduled for completion in early 2022. If successful, construction of an operational station in the northern hemisphere is expected to proceed apace.[7]



Argus station (see https://arxiv.org/pdf/2107.00664.pdf)

EvryScope will provide photometry of the entire sky over many years–data that have been professionally gathered and consistently reduced. It will set a standard against which other sources of data will be judged.

6 EvryScope cameras have filter wheels, but the system will initially operate in a single passband (currently g').
7 Argus is planned to sample in g' and a second very wide passband.

Quick review of metadata

When a magnitude is submitted to the AID it is supposed to be accompanied by supporting information. Here is a quick rundown of the important items for those who are not familiar with the "extended format" for reports of electronic observations:

- Statistical uncertainty or error of the measurement
- Identities of the comparison and check stars
- Instrumental magnitudes of the comparison and check stars
- Chart from which the comparison magnitude is taken
- Airmass of the observation
- Comments about the observation (sometimes used for additional metadata)
- Identity of the software used to reduce the data

The Julian date and passband are, of course, metadata, and WebObs requires that those items be provided. It does not demand the presence of the other metadata listed here.

If an ensemble is used for reduction, the comparison will be identified as "ensemble." There is usually no indication of what stars were used in the ensemble.

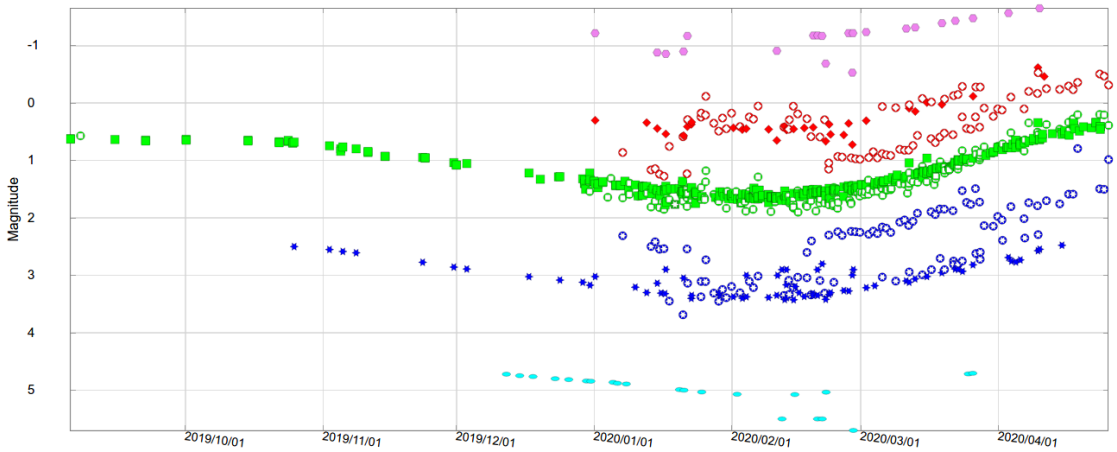
It is a not-uncommon mistake for the observer to report catalog magnitudes for the comparison and check star.

Some observers will report the software as "EXCEL" without any indication of the actual spreadsheet in use, making the reduction untraceable. Occasionally, someone will report "TEXT EDITOR."

Some example photometry problems

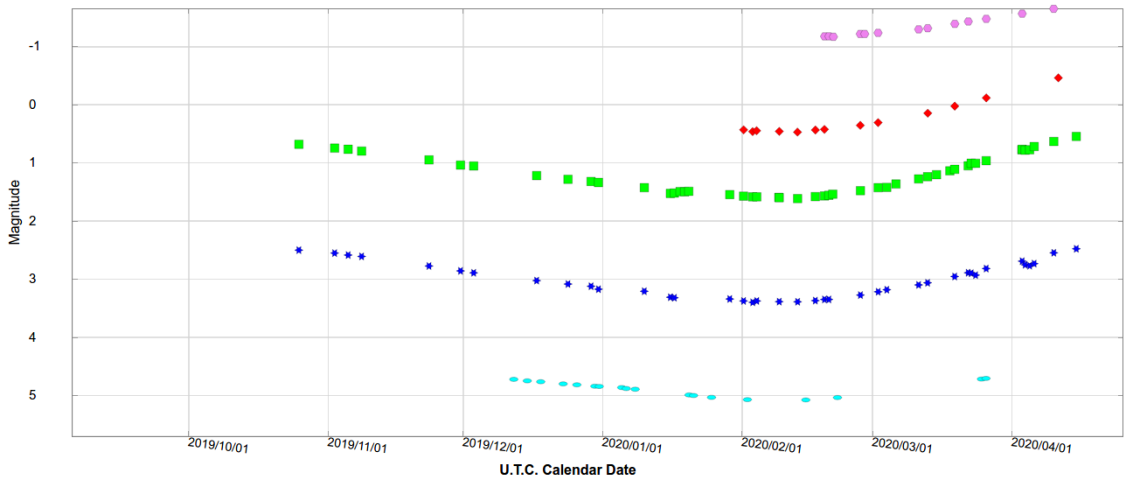
Betelgeuse

An "outsider" coming to AAVSO for data will doubtless first see those data in the light curve generator. Consider what would be presented for the great dimming of Betelgeuse (UBVRI only):



UBVRI of the Great Dimming

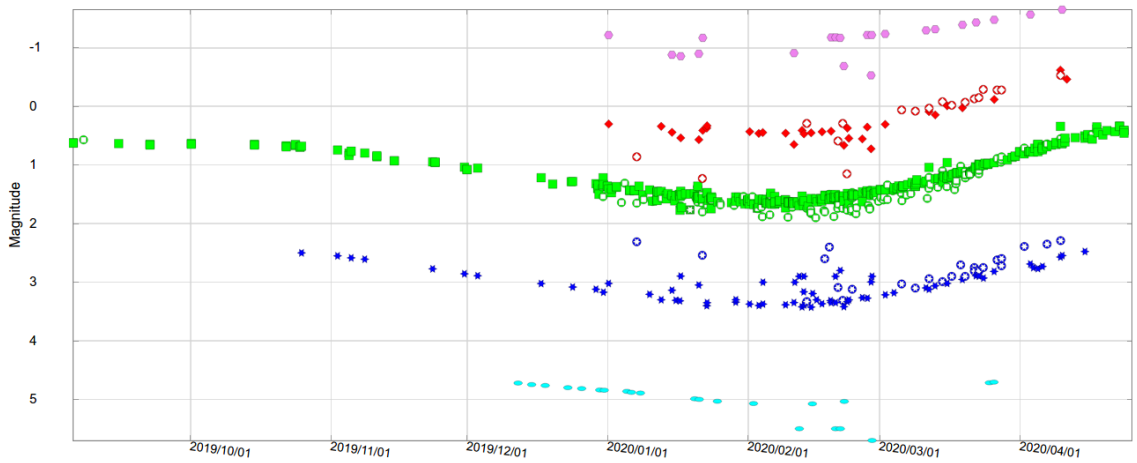
What would a newcomer make of this? There are clearly a lot of discrepancies. He or she will ask themselves, *Is it worth trying to sort this out?* Keep in mind that the LCG offers no clue that help is available or how to get it. As leader of the PEP section, I find this situation highly frustrating, for my observers returned very good data:



PEP light curve

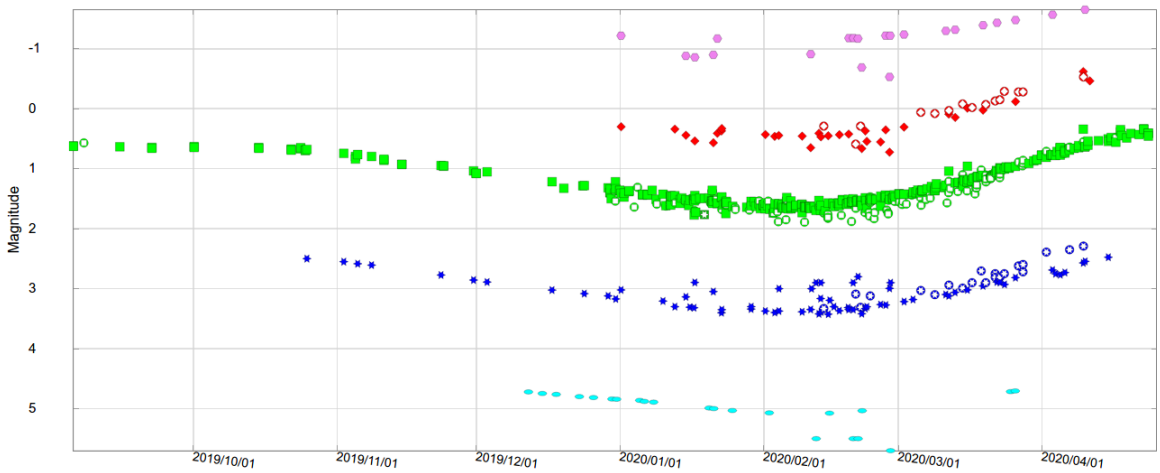
A professional to whom I showed this curve said it was "tremendous," but how would it ever be found among the chaff? I have been trying to raise awareness of these data. In particular I submitted a poster for the 2021 Cambridge Workshop on Cool Stars. But what good that has done is unclear.

The noise in the light curve came from DSLR and CCD observers and was most pronounced in the B and R bands. Much of the trouble can be eliminated by dropping one DSLR observer, whose work was poor and who did not engage with entreaties from HQ:



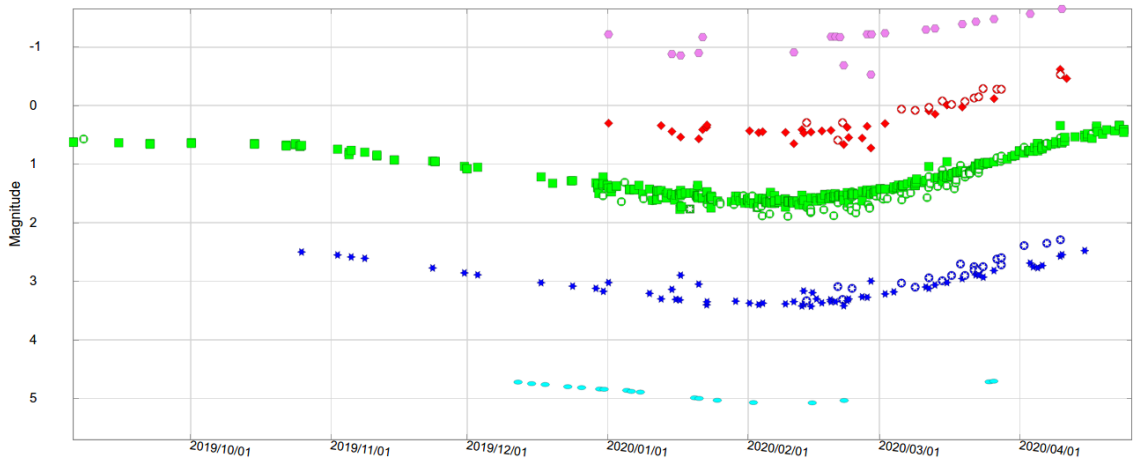
Omitting one DSLR observer

This curve is now better, but there are still erratic contributions. If we drop four more DSLR observers, the situation improves again:



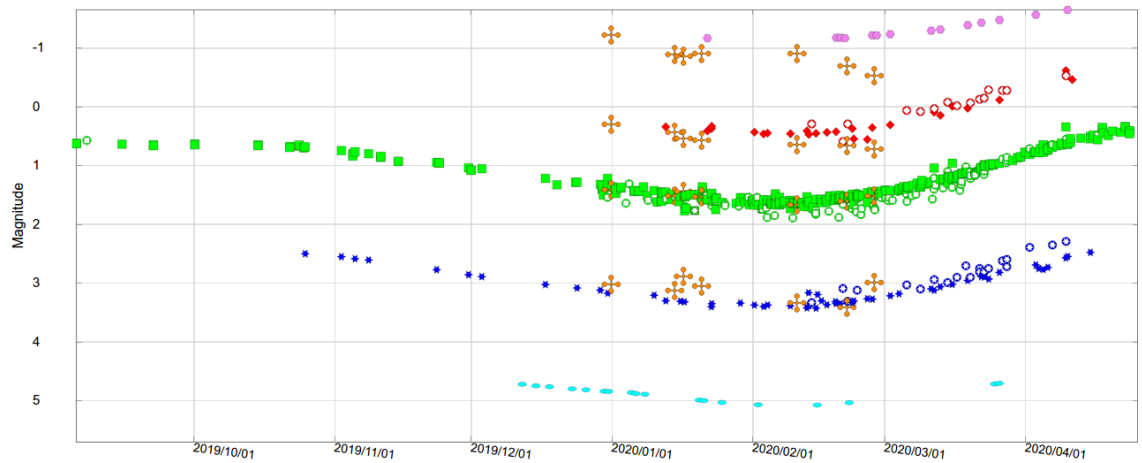
Omitting four additional DSLR observers

The remaining difficulty is with CCD data. By eliminating one novice observer we have:



Omitting novice CCD observer

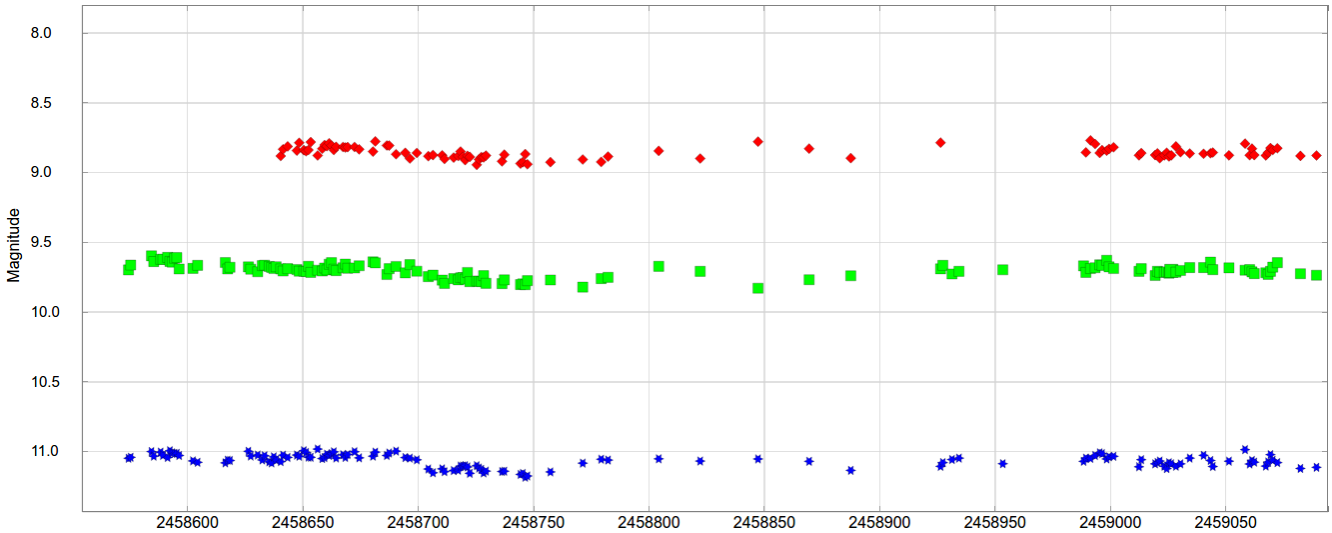
Most of the residual trouble comes from one contributor, a highly experienced photometrist. Success with his first observations presumably lulled him into a false sense of security and he didn't check his later data, some of which surely had linearity problems:



Highlighted CCD observer. First night of BVRI data look good. Trouble later on.

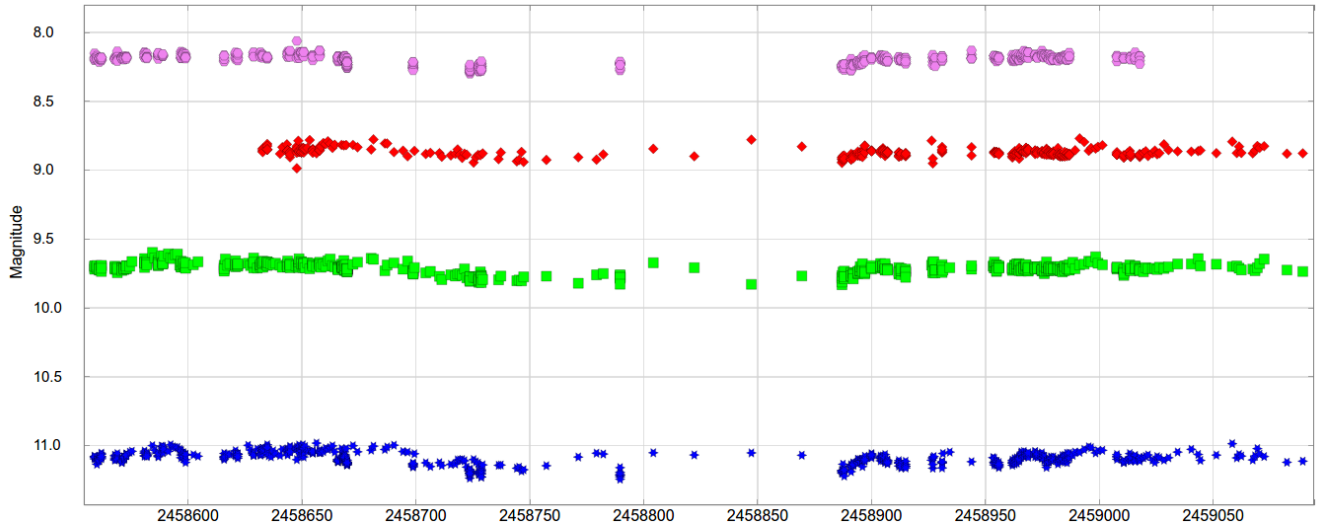
AG Dra

Let's look at some data from April 2019 through August 2020. Below is the BVR light curve from a single observer, A7F, whom I consider reliable.



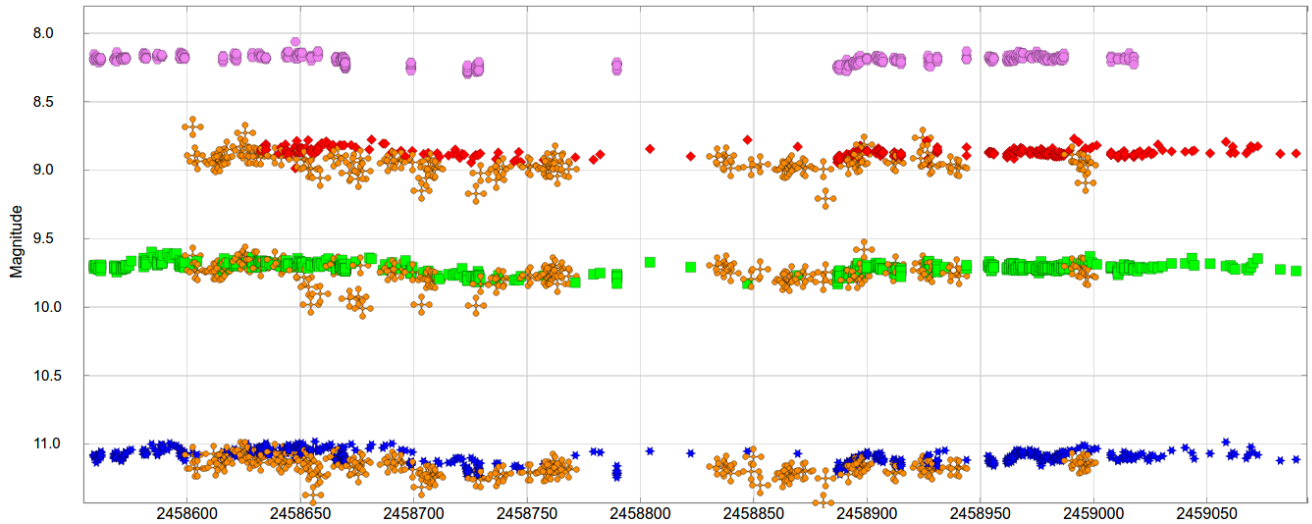
Observer A7F

The most prolific observer is K0W, who seems to align well with A7F and who also works in I band, which I will need in a moment. He is added, below.



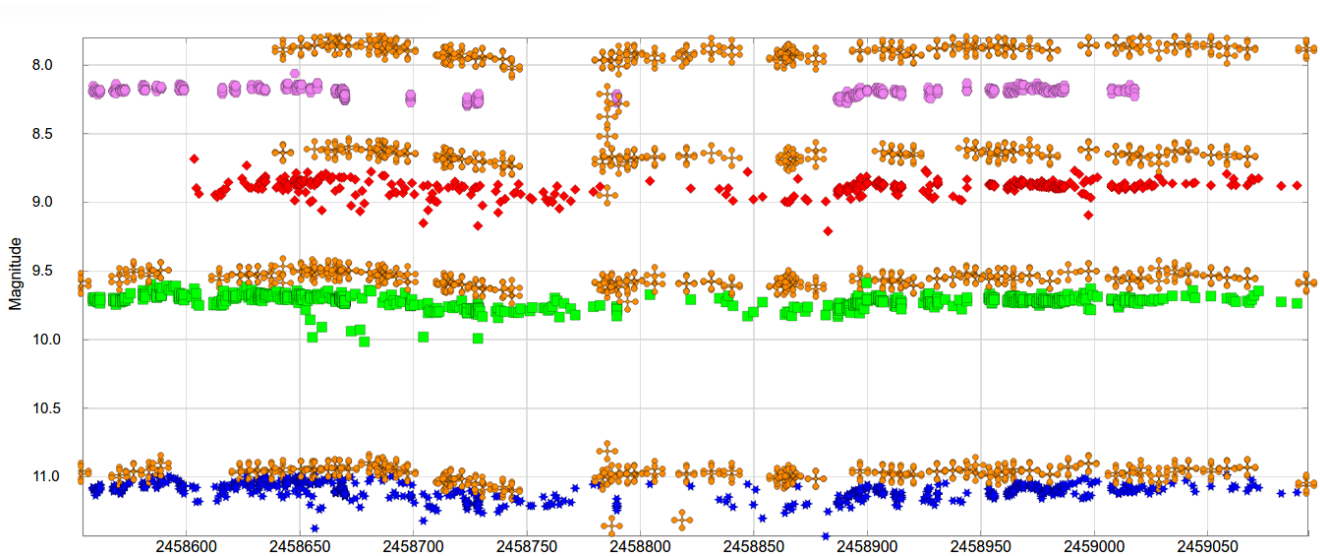
Observers A7F and K0W

If we now add Q99, we see that he appears systematically faint in B&R, and perhaps faint in V. [Remember that this four band light curve compresses data points vertically, making them appear to be in greater agreement than they really are.]



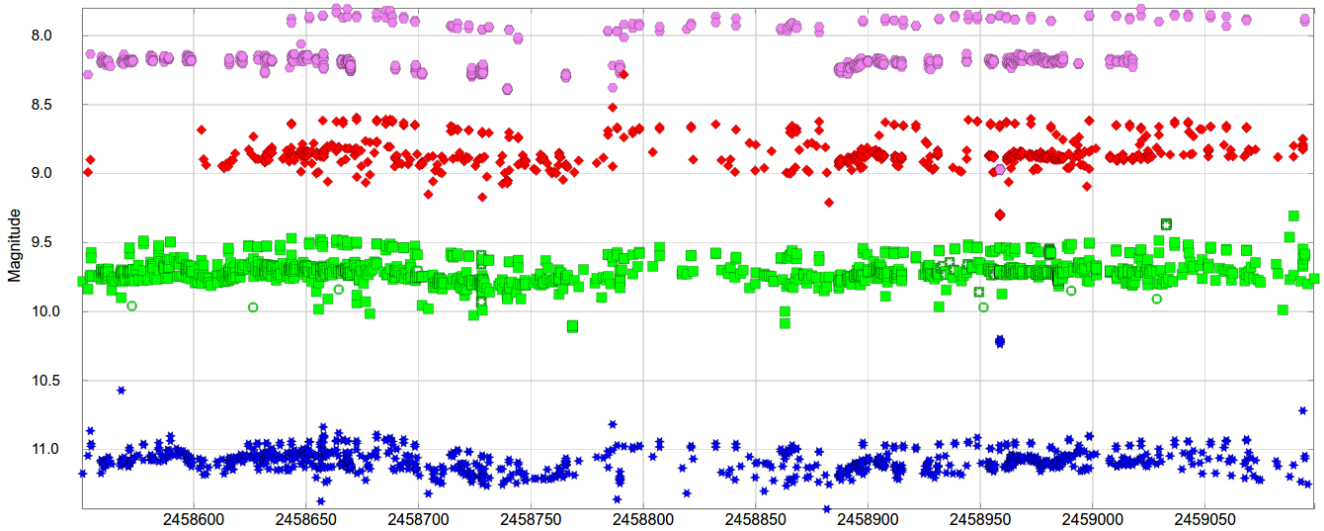
A7F and K0W with Q99 marked

Alternatively, consider U81, who clearly is systematically bright in BRVI:



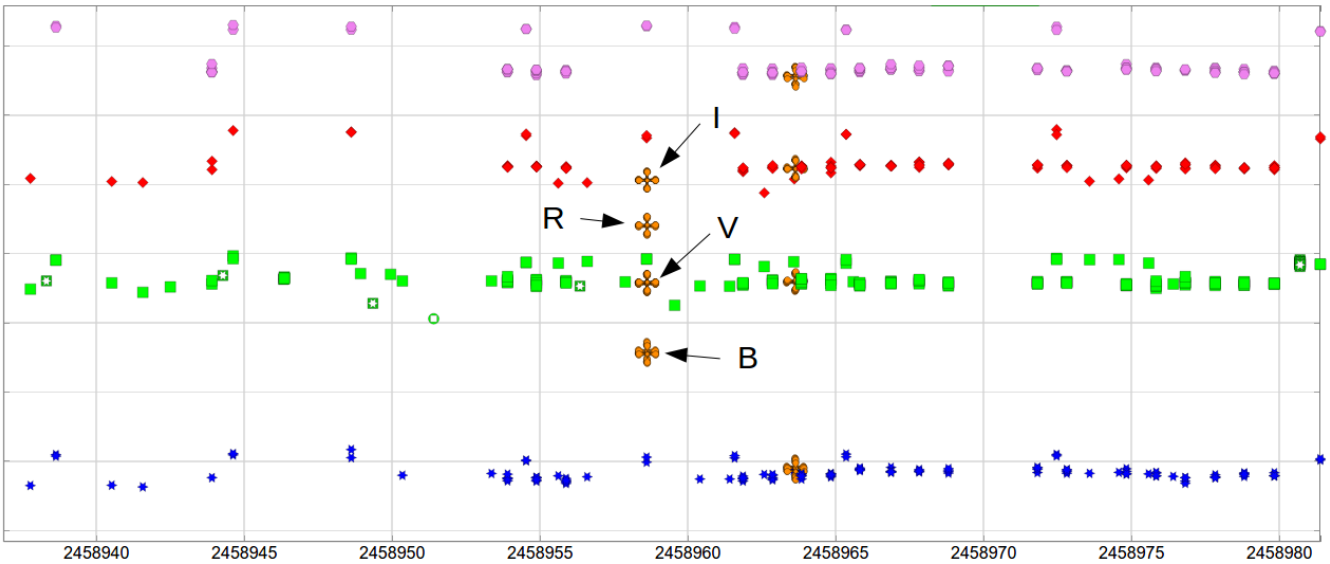
A7F and K0W with U81 marked

I would like to point out that these data have been in the AID for up to 2½ years. Either no one has noticed the problems or no one has time to sort them out. The contributions of all observers are illustrated below. Like the example of Betelgeuse, these data do not inspire immediate confidence:



All observers

Below, observer FQ5 is marked. He has a curious quartet of BVRI data points at 2458958, where BR&I are wildly wrong:

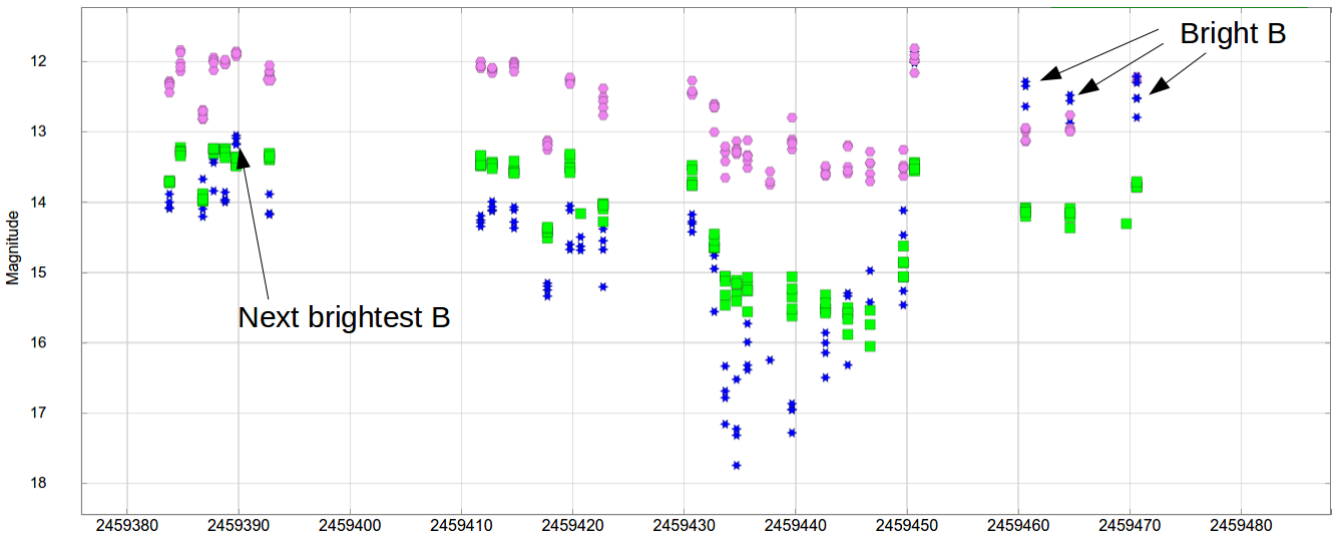


FQ5 on 2458958 and 2458963 highlighted

This individual points are actually a time series, compressed on the scale of this diagram. The data are ensemble-reduced, and FQ5 can be commended for reportng the check star magnitude. One might want to compare the check star magnitudes of this quartet against those of a later quartet of points on 2458963, whose target magnitudes seem to be reasonably good. Unfortunately, FQ5 reduced them, instead, with a single comparison star and a different check star. This makes any diagnostic comparison difficult.

AM Her

K0W did well on AG Dra, but he is a puzzle for AM Her circa 2459430. His uncertainties are large: the BVI median errors, respectively, being 0.100, 0.143, and 0.077 for the data shown below. The errors worsen dramatically as the star fades, reaching over 0.5 in all three bands. K0W is to be commended for his metadata, but therein I spotted something disturbing: his B band transformation coefficient is listed as 0.492. Either that's a typographical error, or his transform calibration went terribly wrong, or he has a defective filter.[8]



K0W data for AM Her (additional bright B points hidden under I band on 2459450)

Above, notice that he has three nights of B band magnitudes at the far right that are much brighter than V. Perhaps this "polar" variable is capable of such behavior, but a look at the instrumental magnitudes[9] raises questions. They are discordant with the night of 2459389, which has the brightest B magnitudes other than the right-hand trio. For example

night	variable mean instrumental B	comparison mean instrumental B	variable-comparison (approx)	mean reduced B
2459389	14.83	13.81	**1.0**	**13.12**
2459460	15.46	14.12	**1.3**	**12.42**

On 2459460, the variable was, relative to the comp, ~0.3 fainter than on 2459389, but it has a *brighter* reduced magnitude.[10] The high uncertainties (0.29-0.57) among the trio data points confound clear analysis of the situation, but they, themselves raise questions. How is he computing them? For instance, the metadata for 2459464.63386 indicate a Poisson error of only 0.052 on the variable, but 0.471 on the reduced magnitude. The comparison is actually brighter than the target, so its Poisson error cannot be all that much larger, and the stated catalog uncertainty of the comparison is only 0.015. By what arithmetic does all that yield a total error of 0.471?[11]

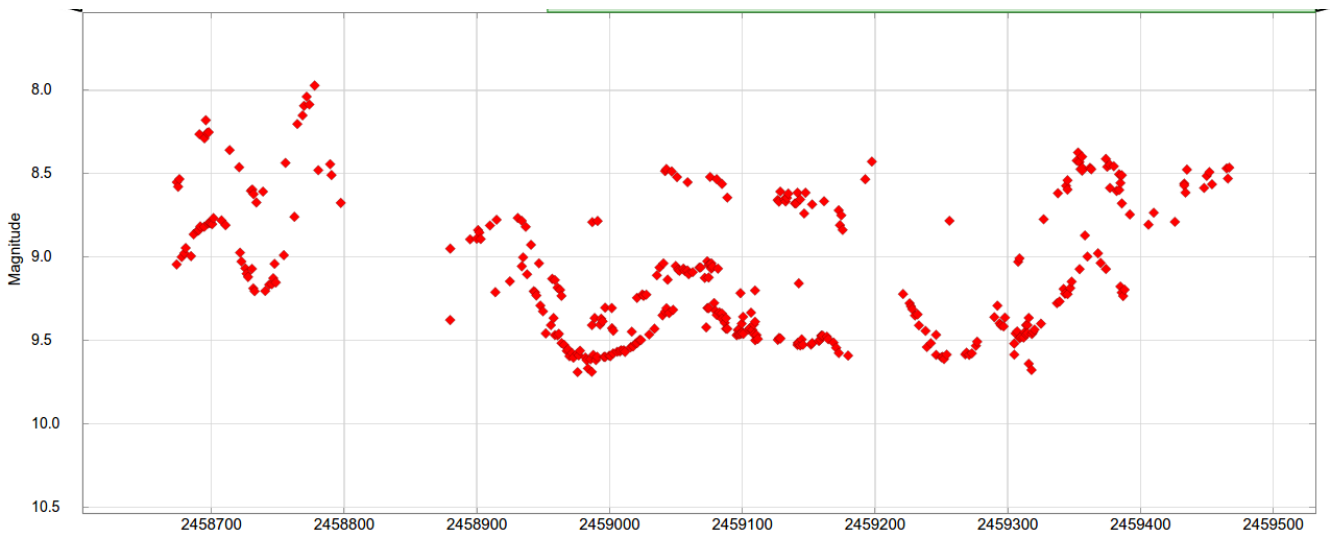
8 His I band transform is also quite large at -0.27.
9 K0W's metadata includes the variable's instrumental magnitude.
10 See additional comments about instrumental magnitudes in "Regarding Diagnostic Tools."
11 And why, on 2459443, did he start reducing V in the VI color instead of the BV color?

Quick Aside

During October 2021, observer TT3 was chronically submitting duplicate observations.

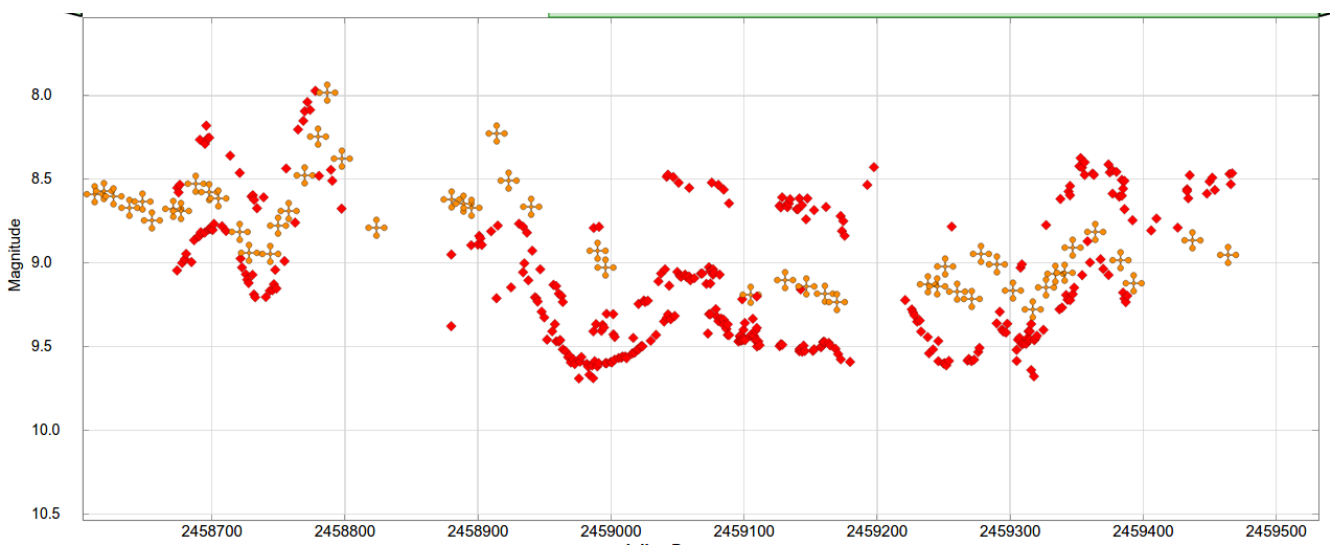
TZ Cyg

Consider an R band light curve, contributed by just two observers:



TZ Cyg by Q99 and E95

We'll highlight Q99:



Q99 highlighted

Q99's data look fairly smooth and I'll use them as the standard. All the other observations are from E95, and there are clearly problems. Not only are his magnitudes offset from Q99, they are offset both above and below, and sometimes on both sides on the same night.

On 2458694, E95 took data at day fractions of 0.60 and 0.76, a little under four hours apart:

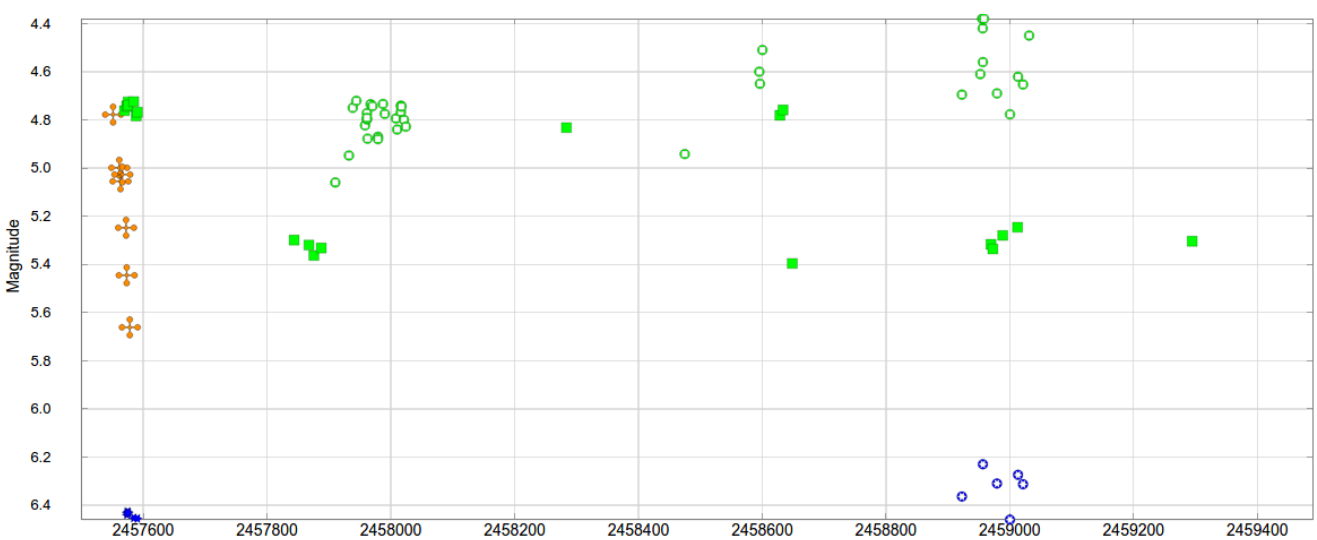
time	airmass	reduced R
2458694.60	1.023	8.819
2458694.76	1.051	8.389

He reports about 0.45 magnitude brightening between the observations, which seems very unlikely. I note that for the airmass to change so little in ~4 hours, the target must be transiting in between. Looking at the respective times of bright and dim magnitudes in his light curve, I think it is safe to say that all the dim measurements were taken on the east side of the meridian and all the bright ones on the west side. I guessed that E95 had a German Equatorial mount, and that meridian flips were somehow messing up his data reductions.

In fact, E95 was using two different comparison stars, identified as "116" before transit and "124" after. He apparently applied the 116 reference magnitude to reductions with star 124, which would produce exactly the kind of behavior seen here.[12] Even so, this mistake does not explain why E95's east-side data are fainter than Q99. [Admittedly, it is possible that HKEB is too bright].

W Boo

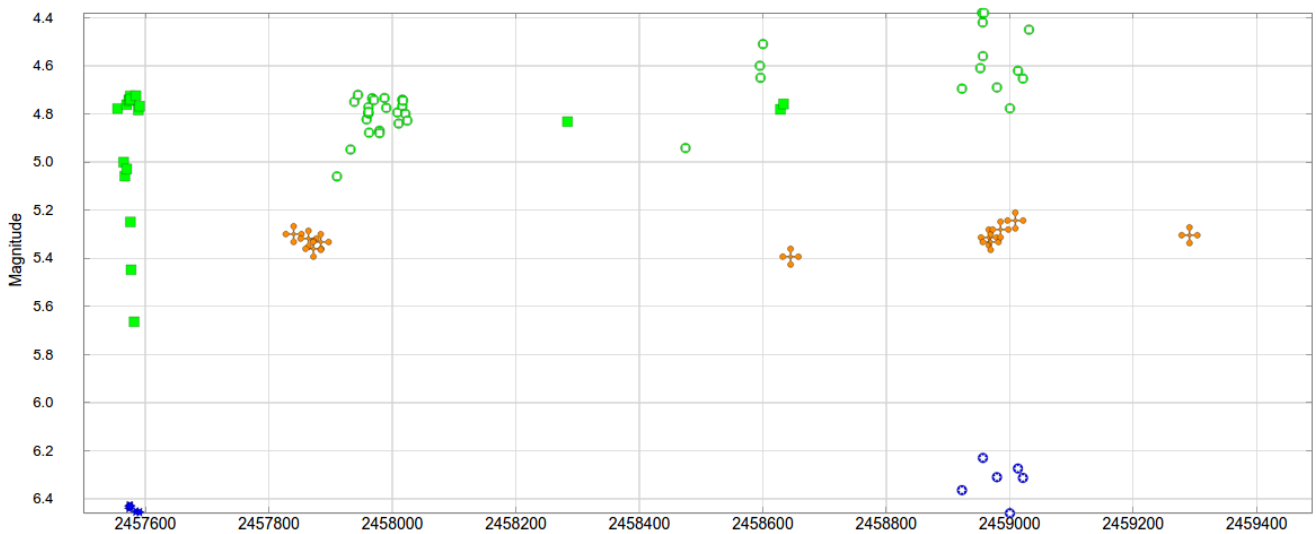
Below is a light curve with DSLR and PEP observations, but here it is some PEP observers who went wrong (it does happen).



X4T highlighted

X4T, who reported the downward cascade at far left, is a problem observer who largely refuses to engage with PEP leadership. Below is observer Z5W, who is generally reliable but here seems to be using the wrong comparison star:

12 The analysis is complicated by the fact that his chart has two 116 stars and two 124 stars (a metadata problem).

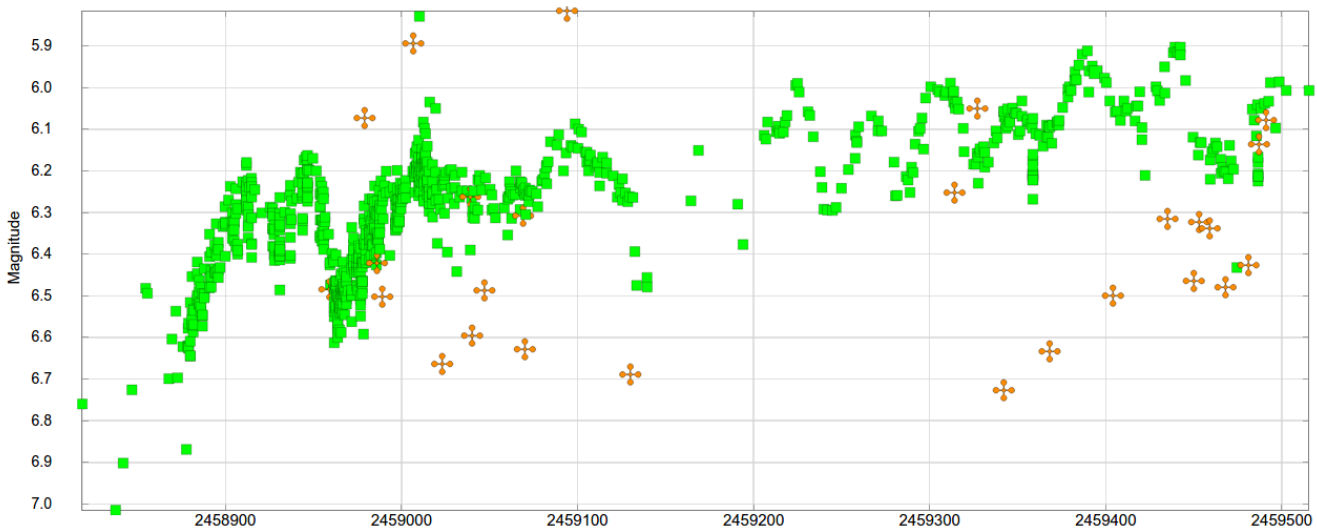


Z5W highlighted

The other V data points are from experienced PEP observers. The TG and TB data circa 245900 show considerable scatter, but their B-V values are not unreasonable.

R CrB

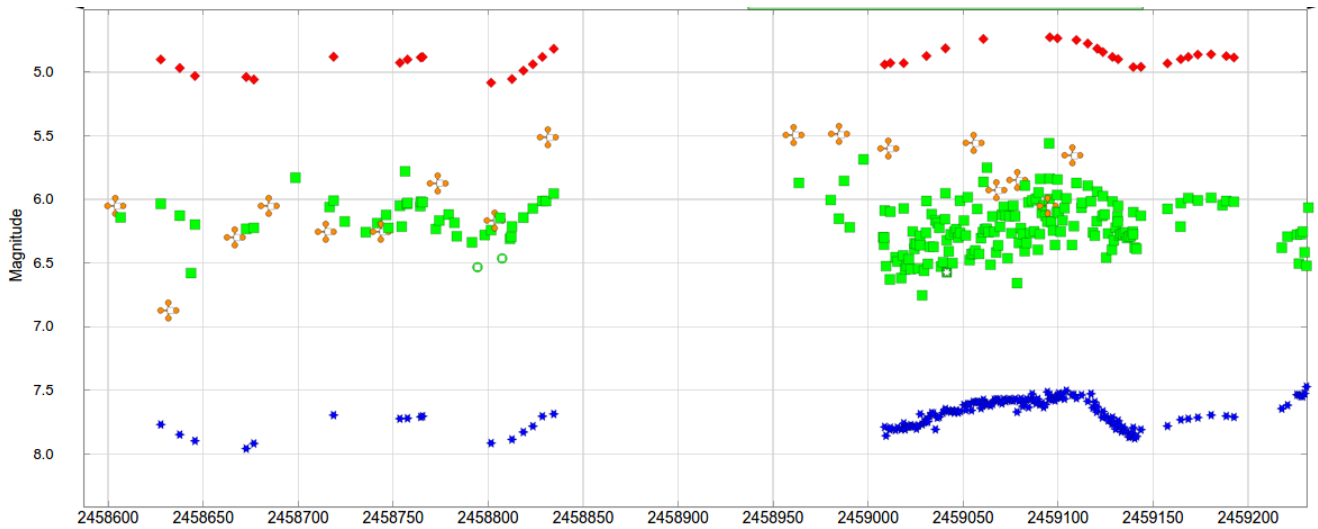
CCD observer W11 (highlighted) shows tremendous scatter in V band.



His reported magnitudes for the comparison and check star are reference, not instrumental, magnitudes. He also does not report airmass. There is really no information to help diagnose what is going on. While the profusion of dim readings for this bright star suggests saturation, thre are bright points that cannot be similarly explained.

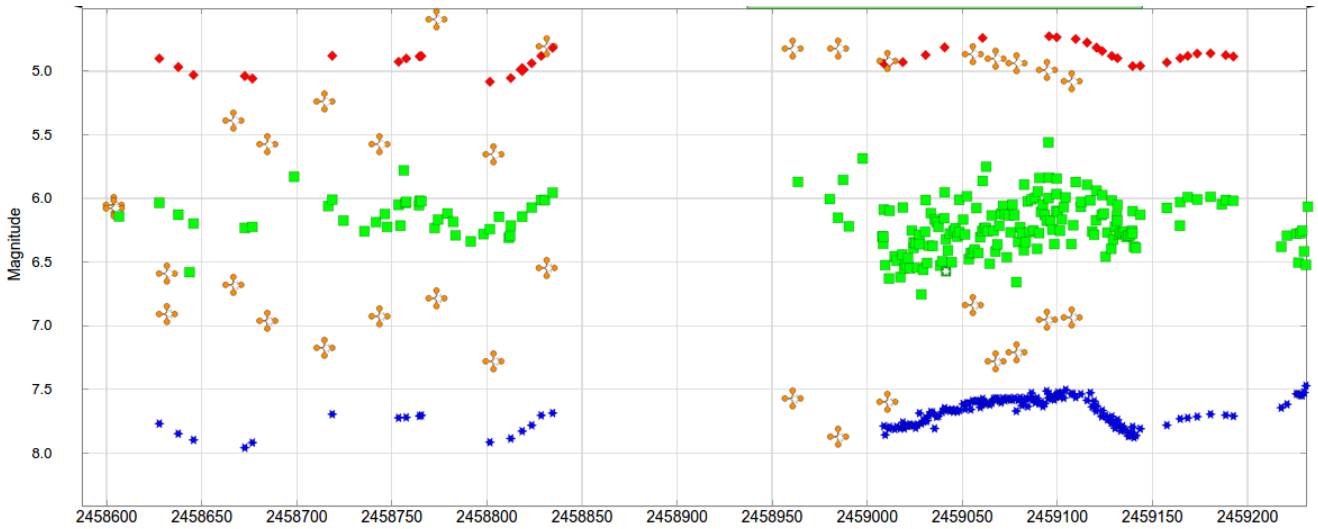
XY Lyr/VV Cep

DSLR observer Y6Q also has a lot of scatter. He concentrates on M stars, submitting tricolor RGB data. Below his TG points are highlighted.



Y6Q TG highlighted

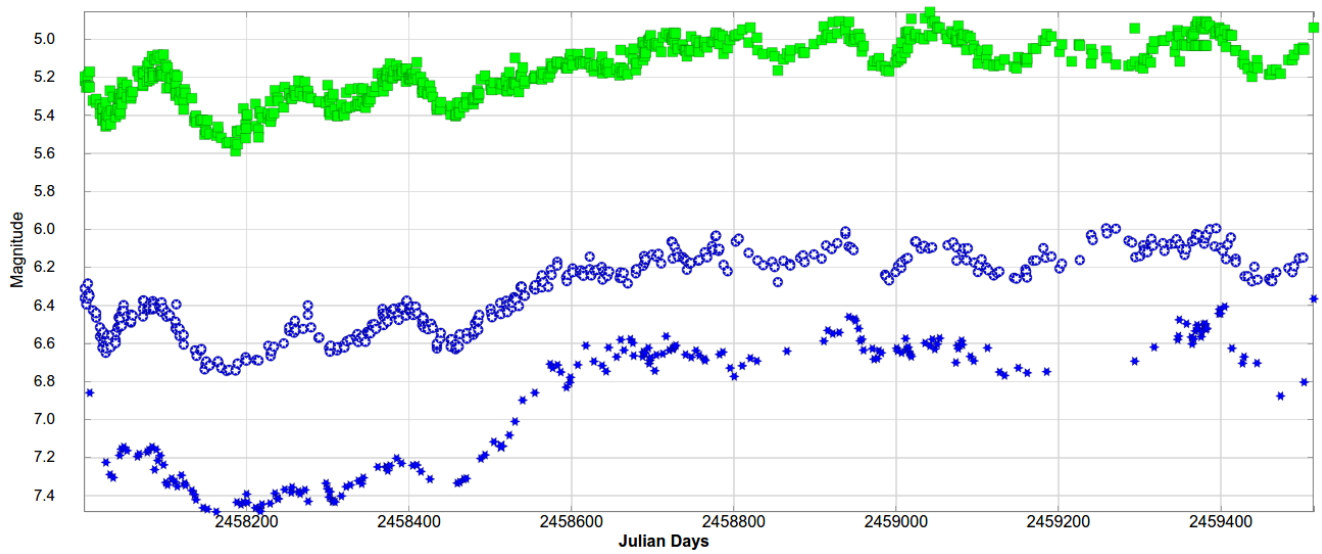
Not very good. The TB and TR points have their own problems:



Y6Q TB and TR data highlighted

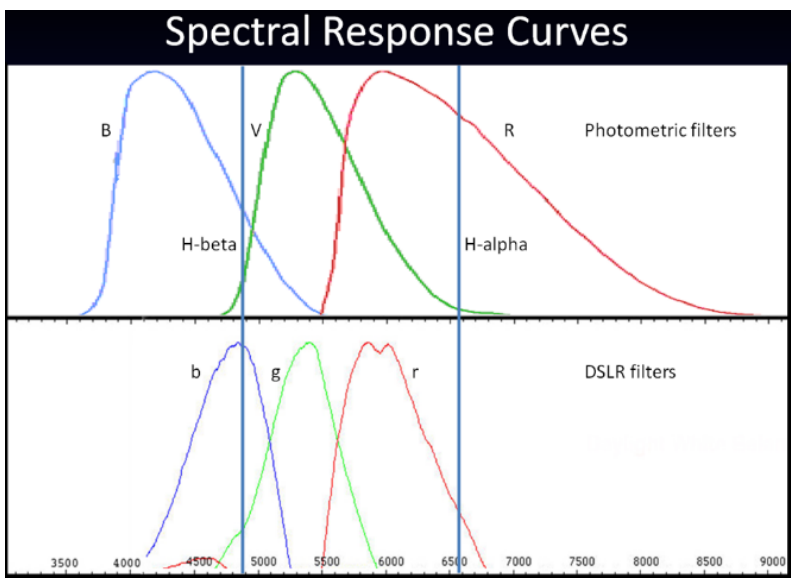
Y6Q was inconsistent in his choice of comparison stars–sometimes using different comparisons in different bands on the same night. Other M stars that Y6Q observed also showed considerable scatter in TG (there were generally not B and R magnitudes from other observers to check against his TB and TR).

Y6Q is erratic–his technique is probably not good. But he may also be suffering on account of using DSLR passbands on a very red star. As an analogy, consider the following V, TB, and B data for VV Cep.



P6M (V, TB) and L77 (V, B).

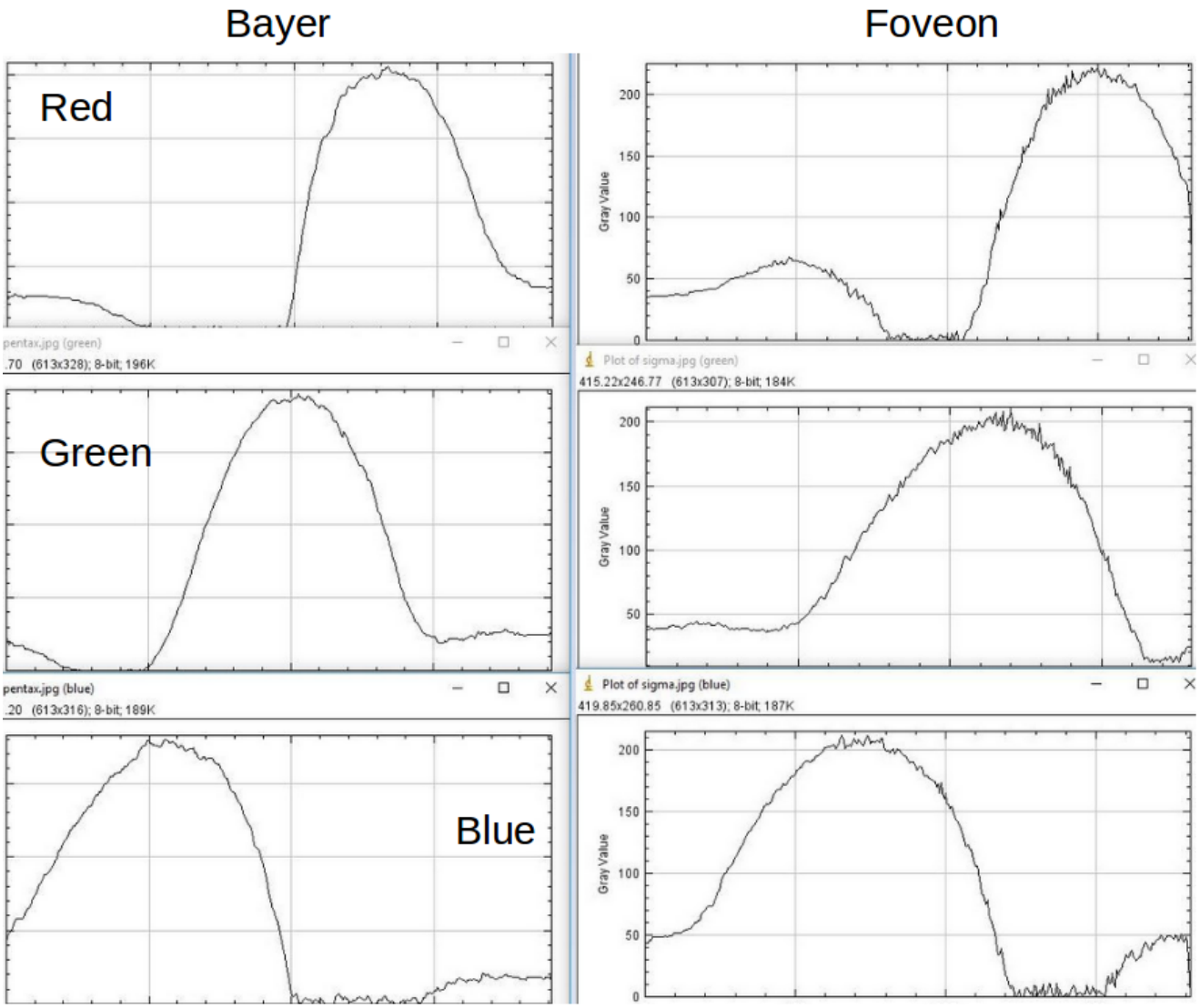
I show only the data from P6M and L77, both of whom are experienced observers. Their V data are in good agreement, but their TB and B data diverge. Who is correct in the blue? L77 unfortunately provides no check star and does not specify his ensemble, nor does he report airmasses. I think, however, that he is closer to the mark. His data are not transformed, but they were taken through a photometric filter. P6M's brighter magnitudes are, I think, due to his non-photometric passband. The blue DSLR channel lies significantly redward of the peak of the Johnson B band. For an M star, TB will pick up considerably more flux than Johnson B (see diagram below).



Mark Blackford's passband chart

P6M is actually using an O9 comparison star, the flux for which likely peaks on the blue tail of the TB passband. This will make the comparison look dim compared to Johnson B. [Either a surplus of variable flux or a shortfall of comparison flux will make the variable look too bright.]

On XY Lyr, Y6Q is generally bright in TB and dim in TR, which could be explained by untransformed DSLR filtering. But the situation is further muddied on account of Y6Q using a non-Bayer array for most of his data. On 2459068, his comment says: "Camera switched to bayer array sensor." It had previously using a Foveon sensor, a device based upon vertically-stacked photodiodes rather than horizontally-spread CMOS pixels. This sensor has a color response yet different from Bayer:



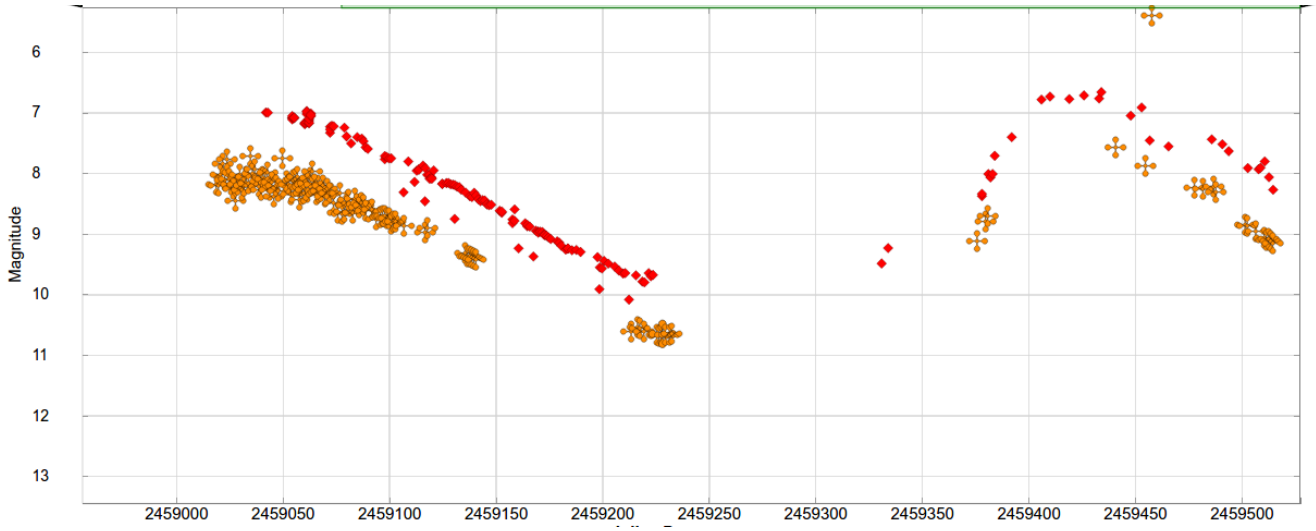
Rough comparison of Bayer and Foveon response (units uncertain).

As can be seen, the Foveon sensor has wider passbands than Bayer, and more contamination from outside the passbands.

Regardless of what RGB sensor is in use, it is not clear that we should be accepting any TB or TR data for very red or very blue stars.

R Aqr

Observer S4E takes data in BVR. His B and V light curves look good, but his R magnitudes are consistently dim.

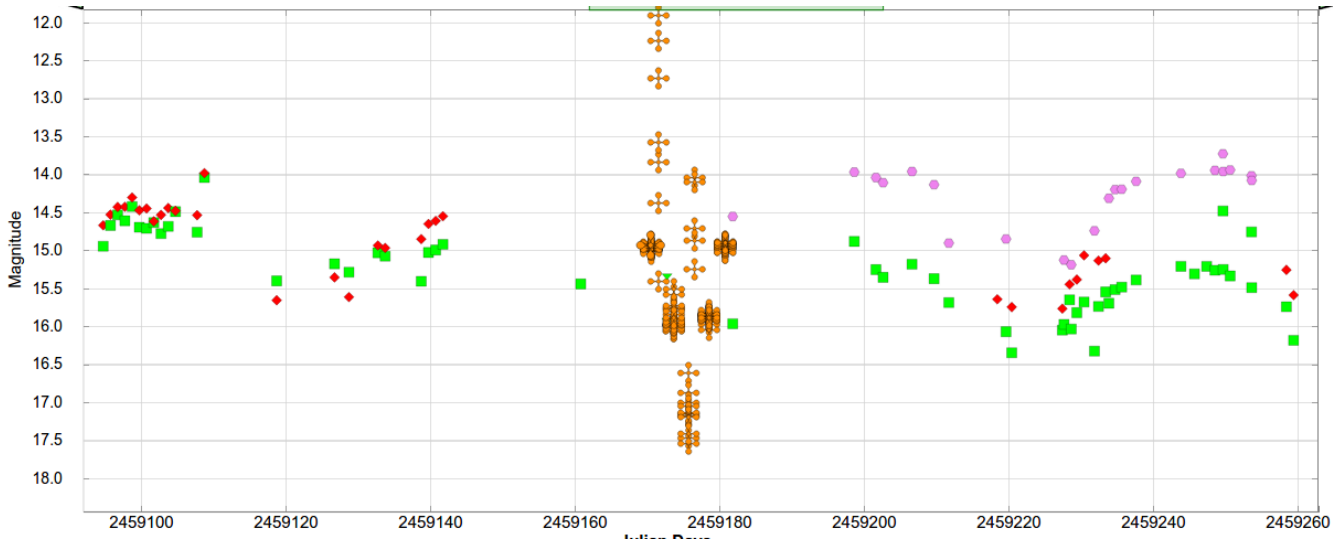


R Aqr in R band. S4E is highlighted. Data from prior years indicate that S4E is faint.

Since B and V are good, he presumably has the correct comparison. His comments include the reference magnitudes for the comparison and check, and the R magnitudes are correct with respect to AAVSO charts. Whether his software is actually using the specified R magnitude for the comp is another matter. On 2459458 he has a very bright R point. The comparison star is supposed to be a full magnitude brighter than the check star, but the instrumental magnitude reported for the comparison is fainter by more than 2½.

V582 Mon

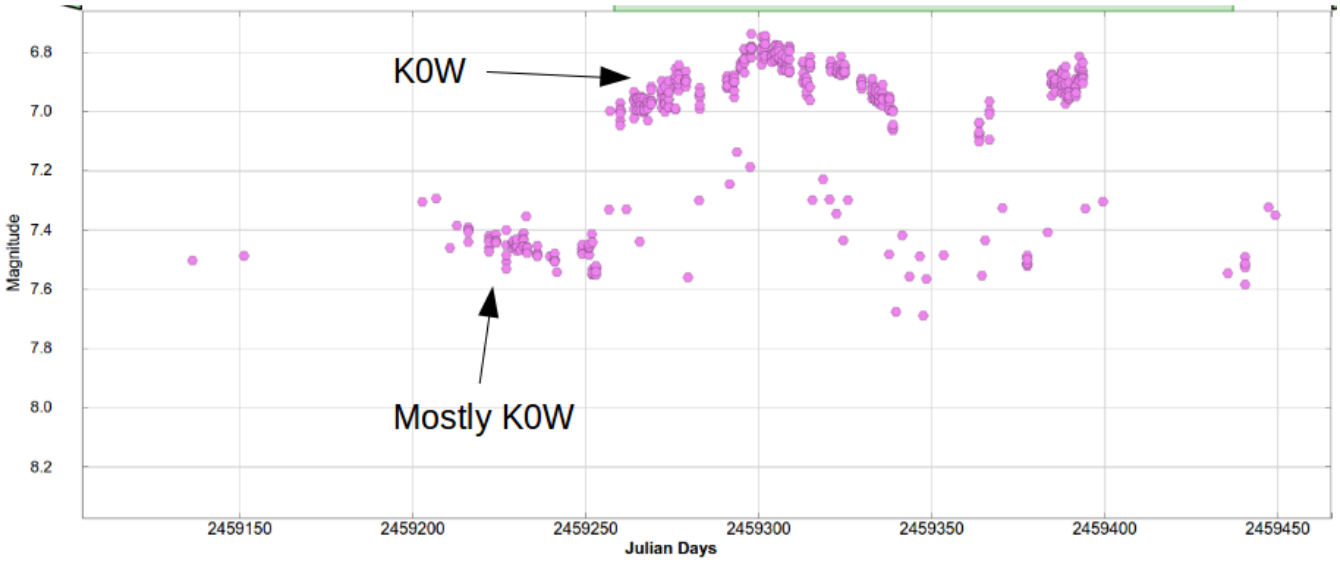
Over twelve nights circa 2459170, KJ9 collected I band data for this star, highlighted below.



During this period, the instrumental magnitudes of the comparison star varied by almost 7, despite the airmass never being above about 1.7 (median was 1.5). On night 2459171 (bright data points) the comparison instrumental magnitude varied by more than 2, despite a nearly constant airmass of 1.5. Seems like there were transparency problems. The data were taken from a remote observatory. The site has a weather station but the apparent incursion by thin clouds was not severe enough to trigger an automatic shutdown. Remote-contol observatories present their own complications for quality control. [Note from Brian Skiff: this star has a bright neighbor 30" away that can cause internal reflections.]

T Crb

Here K0W is struggling again, this time in I band. Most of his densly-gathered magnitudes are too bright.



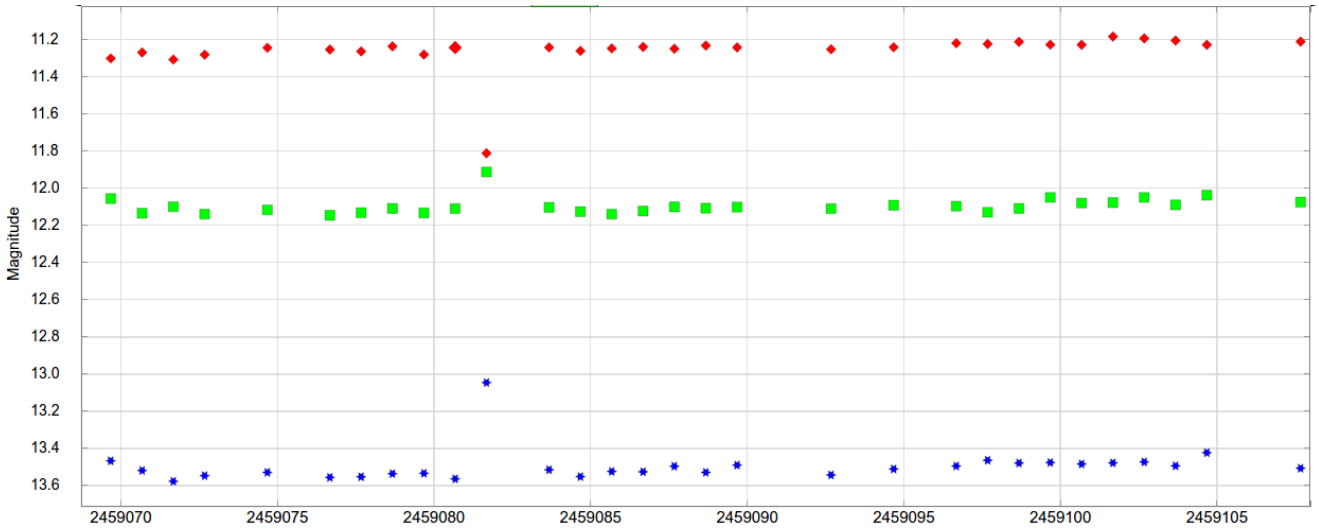
But many of the dimmer data points before and circa 2459250 are also from K0W. He has a sudden jump on 2459257 accompanying a change in transformation.[13] The V-I color delta (based on another observer) is about 1.859. The TI_VI value specified for the dim data is -0.087; for his bright data it is -0.27. The jump from -0.087 to -0.27 would bring about a brightening of 0.34 magnitudes, approximately what we see in the light curve.[14]

Curiously, on his last two dim points K0W appears to do a color-based reduction. There is no TI_VI value, but he specifies TVI=1.064.

13 He continues to use the same comparison star.
14 For AG Dra, above, where I cited K0W as a "good" observer, he was using -0.087 as his transform.

YZ Cet

S4E has a nice BVR light curve for YZ Cet, but on 2459081 things go haywire. The V magnitude is too bright, the B much too bright, and the R much too dim:



S4E having trouble on day 2459081

The check and comparison stars in use have, conveniently, a K-C delta of about 0.4 in all three bands, so that we would expect the instrumental K magnitude to always be about 0.4 fainter than C.[15] Below is a table of actual instrumental deltas for 2459081 and the night before.

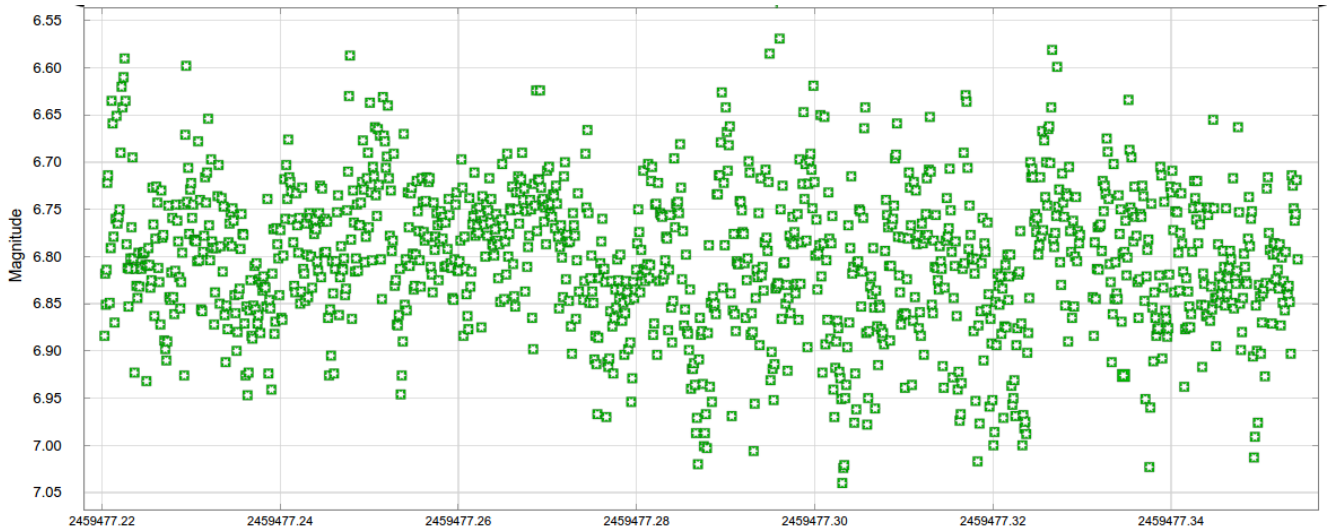
date	B (K-C)	V (K-C)	R (K-C)
2459080	0.37	0.36	0.38
2459081	0.00	0.29	0.78

The instrumental deltas are reasonable for 2459080, but not for 2459081. The V delta is not horrifically wrong, but the B and R are off by about 0.4, though in opposite directions. On S4E's next active night the deltas become reasonable again. I don't know how to interpret this scenario.

15 The stars have almost identical B-V colors of 0.58.

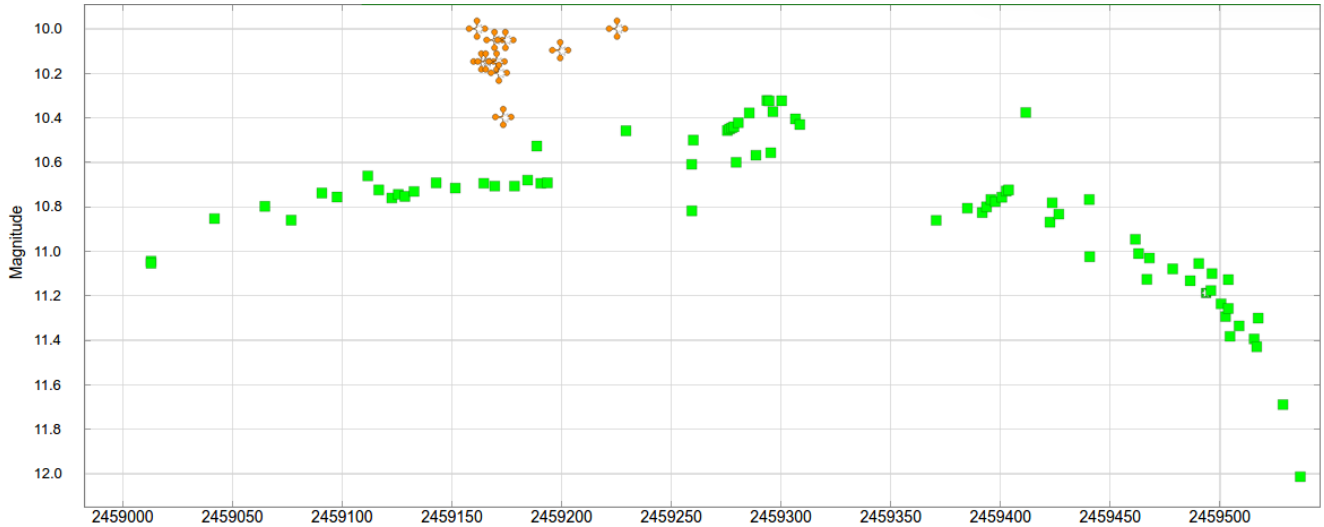
Nova Cas 2021

In 2013, Arne Henden pointed out that novae were bad targets for unfiltered photometry.[16] But for this nova, observer YK7 submitted an absolute torrent of CV data. I will not reproduce the whole light curve; my point is that a mistake identified eight years ago is still being committed. To the extent that past photometric problems have been diagnosed, the lessons learned have not been absorbed by the community. Furthermore, YK7 is shooting on a *ten second* cadence, which means that he is affected by scintillation. An example of his data, below, looks like noise.



DY Per

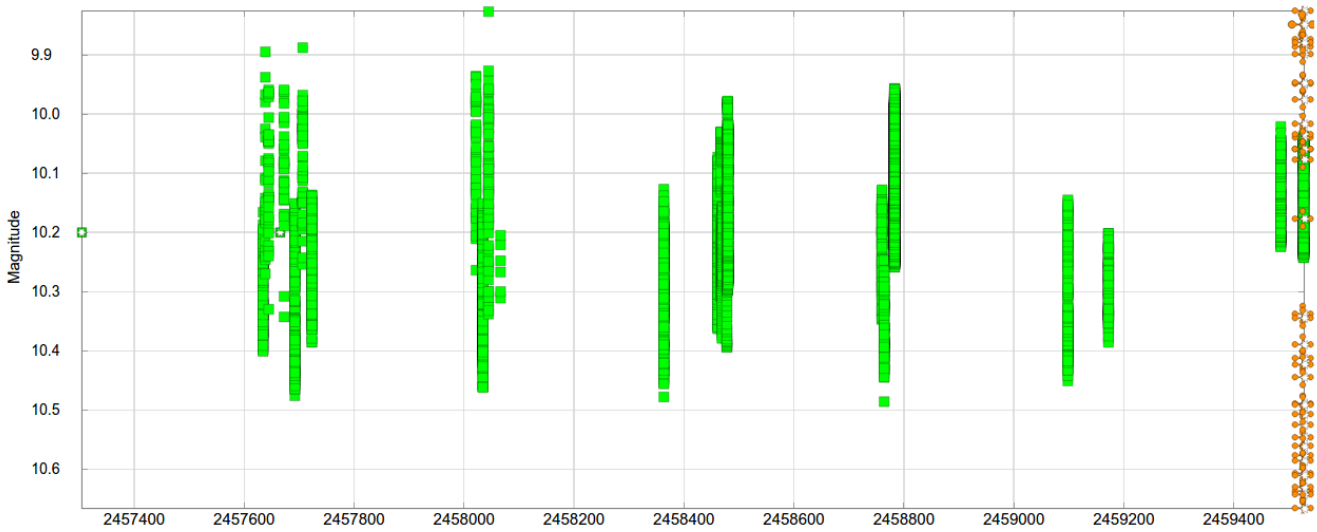
Observer J91 is taking CV data with a CCD. This is a carbon star; J91 cannot possible be using an approriate comparison for unfiltered photometry. What comparison he using is unknown, for he lists it as "NA" and gives no instrumental magnitude. There is no chart, airmass, and apparently no check star, and he lists the uncertainty as 0. This has to be the most egregious example of missing metadata in the AID. The star is about magnitude 10. There is no shortage of light, so why is J91 working in CV? He is highlighted, below.



16 Nova 2013 Del will be considered in more detail below.

VZ PSC

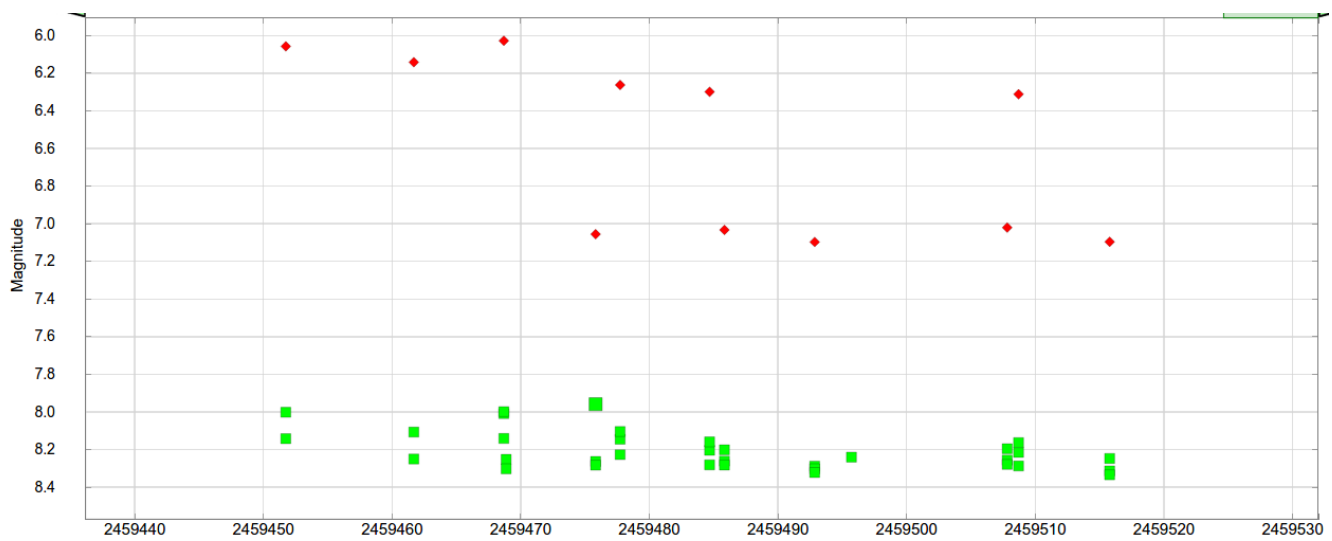
Observer XE4, in CV, is reporting a range of variation nearly twice that of any individual V band observer:[17]



XE4 (in CV) highlighted

NSV 26136

Observer P31 provided the VR data below.

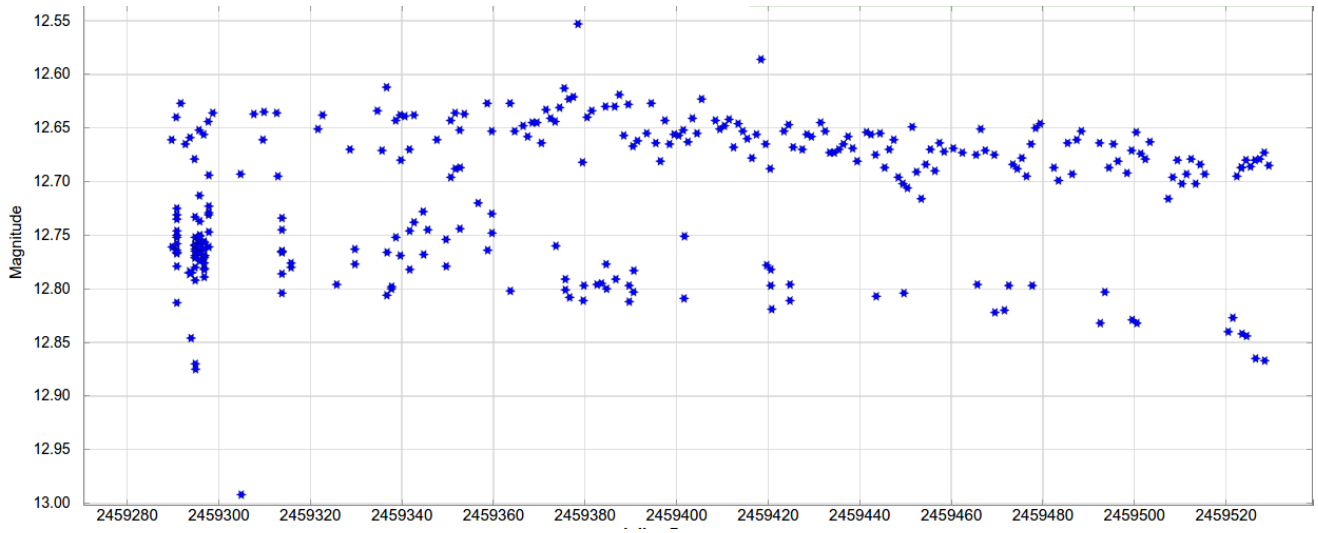


R band shows suspicious jitter. The individual R points are accompanied by two or three V points on the same nights. The multiple V points on any given night typically have the *exact* same time. It's as though P31 is reducing his V data more than one way and reporting all the variations.

17 There are offsets among the V observers. None of them reports as much as 0.5 magnitude variation. XE4 sees almost 0.9.

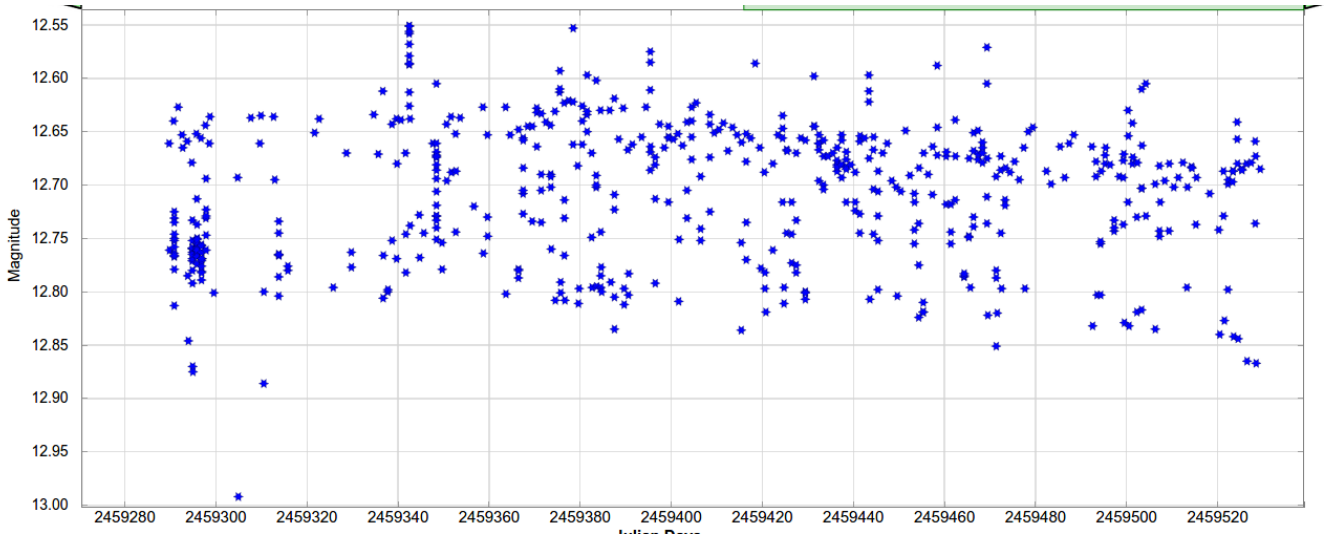
HM Sge

Five observers are reporting an apparently bi-modal light curve in B band.



The top "trace" is almost exclusively from one observer, while the remaining points are from the other four. A grand total of one point has a transformed magnitude.

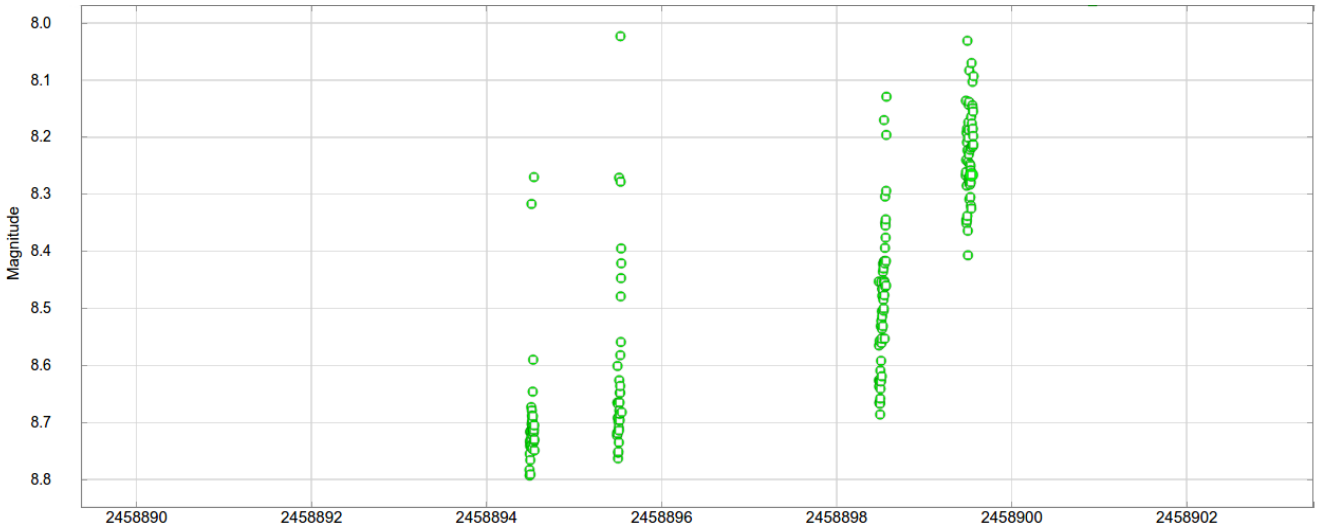
I now add the most prolific observer (who also does not transform).



Given that the actual variation of the star is likely small, the substantial discord among the observers arguably renders this light curve useless (V band is no better).

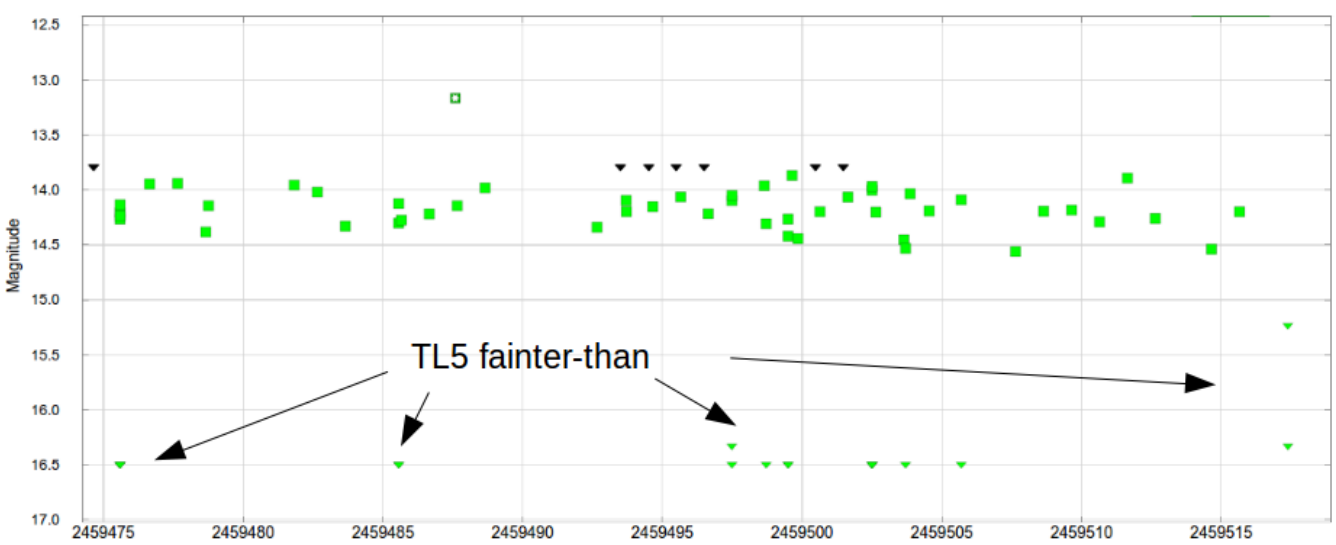
TX Cnc

H4W is too bright (VSX gives maximum of V=10.0). He is apparently using an ensemble of GAIA magnitudes and also reports constant errors of 0.2965 with *brightening* check magnitudes as the airmasses increase each night.



KR Aur

Observer TL5 reports V magnitudes in the range of about 14 to 14.5, and V magnitudes that are fainter than about 16.5. No other observer reports V magnitudes below TL5's fainter-thans, which makes his fainter-thans questionable.

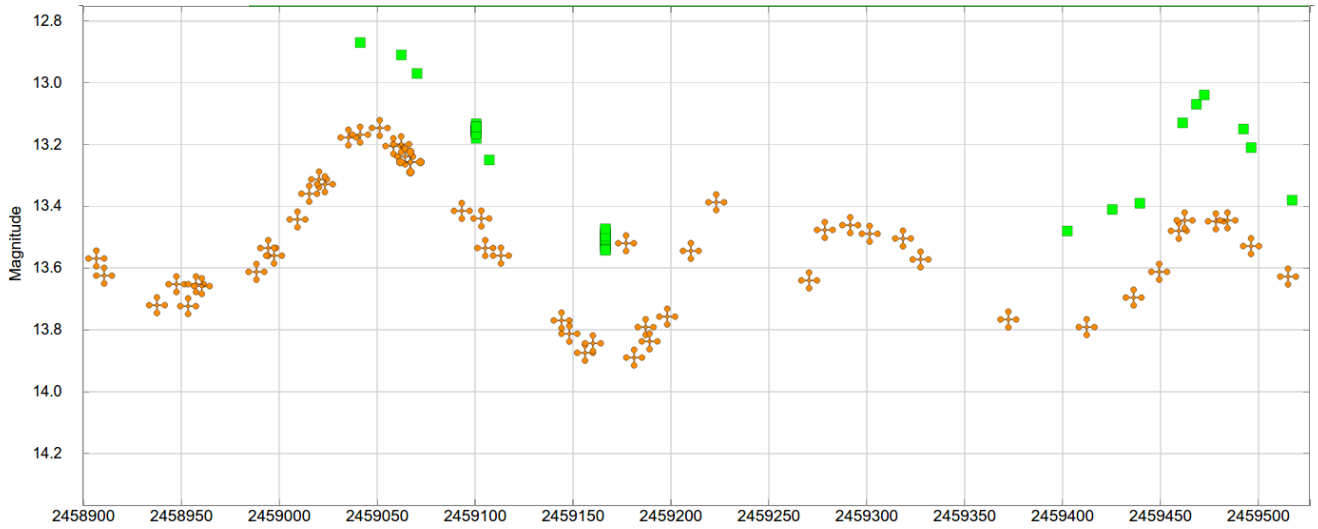


V band fainter-thans (mostly at 16.5) are from TL5

For most of the fainter-than nights, TL5 also reports successful detections at *brighter* magnitudes. Eg: on 2459475, he has V=14.2349, 14.1349, and fainter-than 16.5. And the time for the fainter-than is exactly the same as for V=14.2349. All fainter-thans on the same nights as detections share the same time with one of those detections. This is reminiscent of P31 on NSV 26136, but the problem is more serious. The comments indicate that the reduction is made with a custom pipeline. I'll wager that the pipeline has a bug and TL5 hasn't noticed.

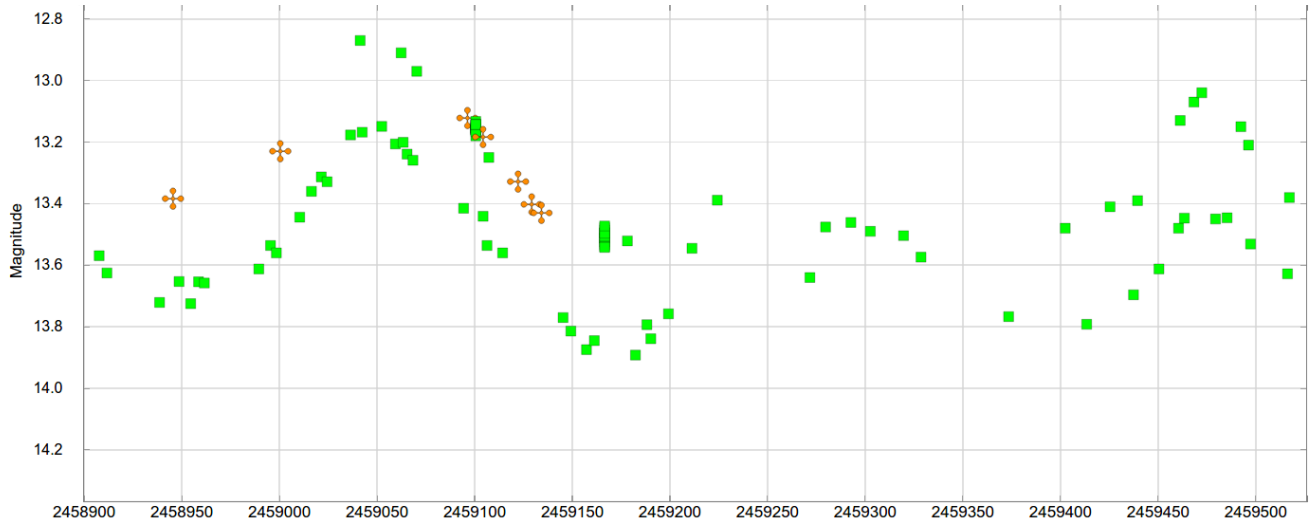
PU Vul

Data for this star also exhibit a dual-trace behavior. Below, observer U81 is highlighted. Other observers, chiefly W4L, are brighter. Whom do we believe?



U81 highlighted

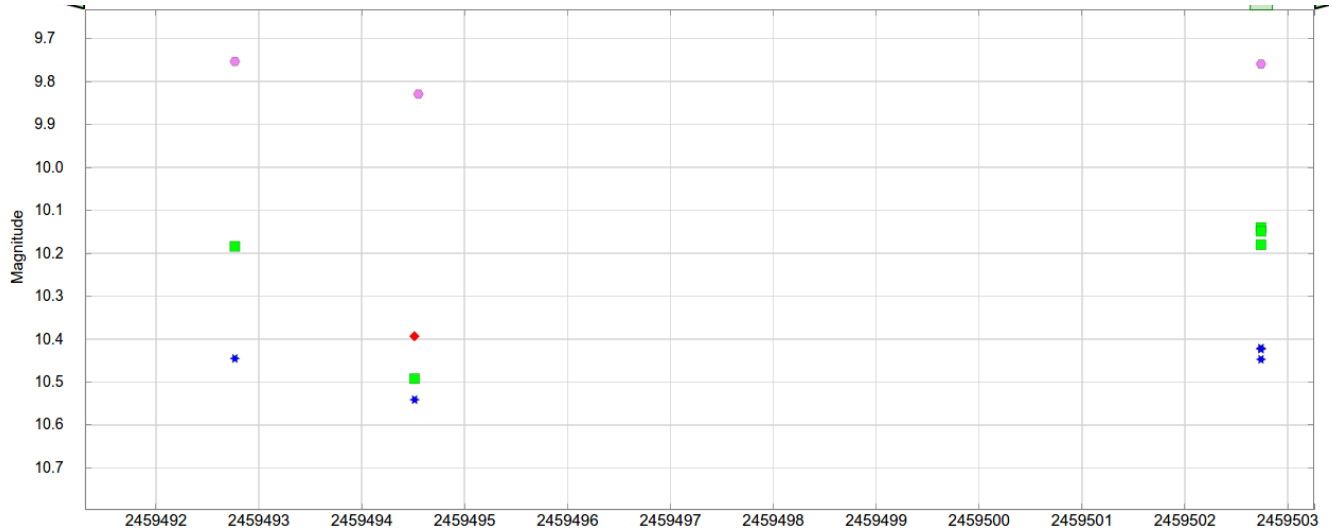
U81 is taking his comparison magnitude from the USNO CCD catalog (UCAC4).[18] The magnitude in question is actually derived from APASS, and the error listed on that magnitude is 0.99. SIMBAD lists a magnitude 0.14 brighter than UCAC4 with a smaller, though still substantial, error. If the comparison is brighter than the U81 thinks it is, his reduced magnitudes for the variable will be too dim, which is what we see.[19] [Note from Brian Skiff: UCAC4 has questionable early-APASS magnitudes.] While we're here, I want to illustrate a problem with the light curve generator. Below is the PU Vul curve with T79 highlighted (T79 is in general agreement with W4L). Careful examination reveals that the points highlighted here have no counterparts in the prior light curve graphic. A data download shows that those points do exist, but the LCG isn't plotting them.



18 He also specifies a UCAC4 source for his BVRI comparison for AG Dra, even though that catalog has no R or I values.
19 Admittedly, the 0.14 difference, alone, is not enough to explain the divergence between U81 and the other observers.

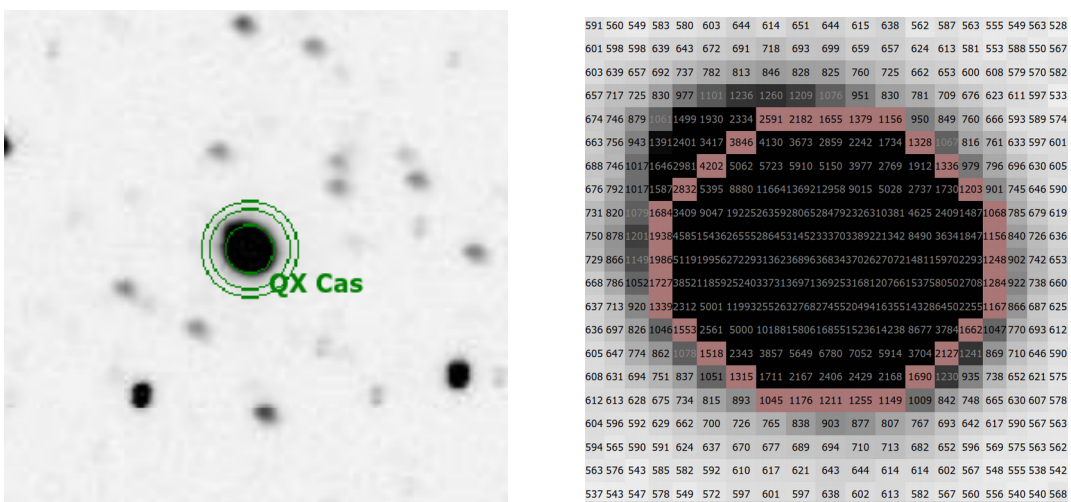
QX Cas

Some BVRI data from M2B are curious. They are the middle "column" of points, below.



All the magnitudes are too dim with respect to other observers.[20] QX Cas was observed in the same field with ER Cas, NSV 26197, GSC 04281-01362 and six other stars[21], magnitudes for all of which were reported. The ER Cas results are also out of step but there are insufficient data from other observers to judge most of the other M2B photometry in this field. It was sampled on 2459479 and 2459494 (above), and the CCD frames for the latter are still available.

The first question to arise is over aperture size. QX Cas shows a FWHM of 5.8; ER has 4.5. Aside from NSV 26197, these are the largest star images under consideration. The VPhot aperture radius selected was only 6, with the annulus starting at 10 having width 2. As the diagrams below show, the aperture does not fully encompass the star. Note that the star image is elongated NE to SW despite its location near the center of the frame.



QX Cas V band with aperture and annulus

20 The comments include transform coefficients, and the note for R band is strange: "TR_VI=-0.1310". I presume that TR_VR or TR_RI was meant.

21 As well as CF Cas, CG Cas, V632 Cas, V654 Cas, NSV 14781, and NSV 26181.

For NSV 26197, the FWHM is 14.5 pixels. The 12 pixel aperture diameter is much too small. The VPhot guide recommends an aperture of 2X the FWHM. The CCD guide, on the other hand, recommends 3-4X the average FWHM of all the target stars. The DSLR manual says 1.2X to 1.5X the largest FWHM. Students in the VPhot CHOICE course are apparently being told to choose a radius by eye. We are giving inconsistent advice.

The comparison star is 121 and the check is 117. Other comparisons, 91 and 131_1[22] are available, and target GSC 04281-01362 is actually listed as a constant star in VSX.[23] The following V band analysis in VPhot used an aperture of 18 pixels, annulus inner radius of 25 and width 7. Six stars were reduced using 121 and 91 as comparisons. In each cell, you see the difference between the measured and expected magnitude. Positive values indicate measurement too dim. Bold italicized entries are significantly discrepant.

comparison ↓	**131** (13.06)	**121** (12.12)	**117** (11.66)	**112** (11.21)	**GSC** (10.84)	**91** (9.11)
121	-0.03	X	-0.04	0.08	***0.42***	***0.91***
91	***-0.94***	***-0.91***	***-0.95***	***-0.83***	***-0.49***	X

The takeaway is that when using 121 as comparison, GSC is noticably dim and 91 is very dim. Star 112 is a little dim. The data hint that as the expected magnitude brightens above about 11.5 or so that the measured magnitude will be too faint. Unfortunately there are not enough suitable reference stars to fully explore this hypothesis. QX Cas roughly fits the pattern: it should have come in at about V=10.18, but using 121 as comp it registers as about 0.3 dim.

Using 91 as a comparison brightens everything by about a magnitude. One could speculate that star 91 experienced nonlinear response, registering as fainter than it actually was. However, the peak count in the aperture is only 44,440.

[Note from Brian Skiff: In the image, above left, the two bright "stars" to lower left and lower right of QX Cas are not real. I will note that the CCD frame contained a very bright star, so we may be dealing with internal reflections.]

Another oddity can be found in reference star 66. Though clearly brighter than 91, the maximum count in the aperture is *lower* by about 6%. Star 66 is closer to the frame center, so, if anything, its PSF is smaller and the flux should be more concentrated.

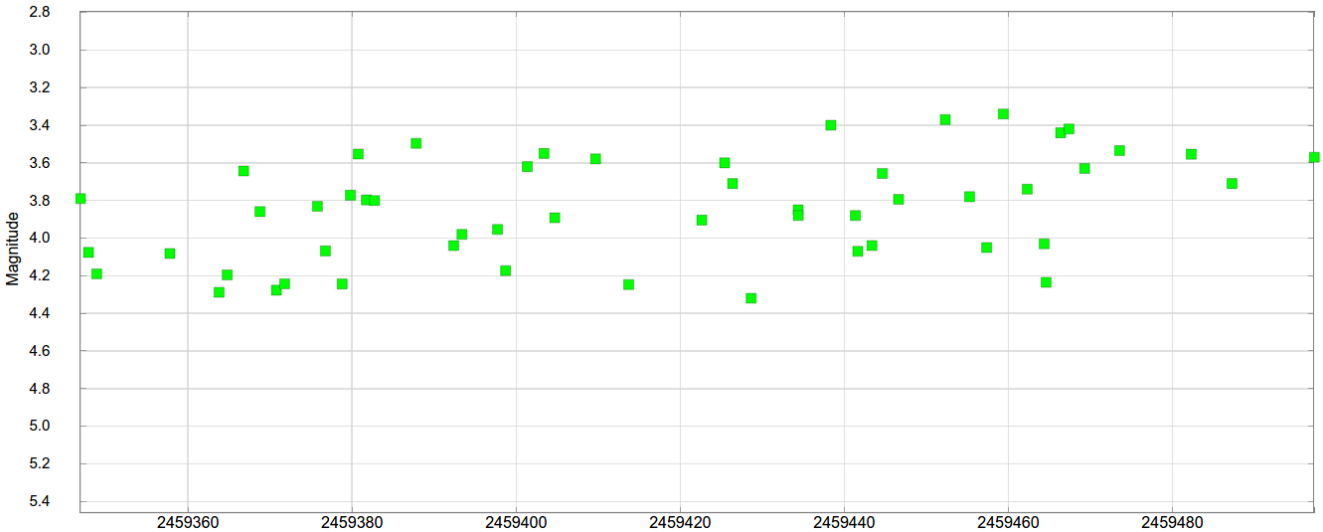
It's worth mentioning that the telescope is corrected Dall-Kirkham with a focal reducer, so there are lenses involved. There is something peculiar going on with regard the the WCS. In RA, there are only 50% more pixels than in Declination. Yet the RA extent is about two degrees while the Declination extent is only about half a degree.

Finally, M2B's metadata do not disclose that the R and I frames were taken through Sloan filters. There was a hint of this in the instrumental magnitudes in R band. The check-minus-comparison instrumental R was about -0.74, but the catalog difference was only -0.29. When observers take data in one passband and then transform them to a fundamentally different passband there should be some note provided.[24]

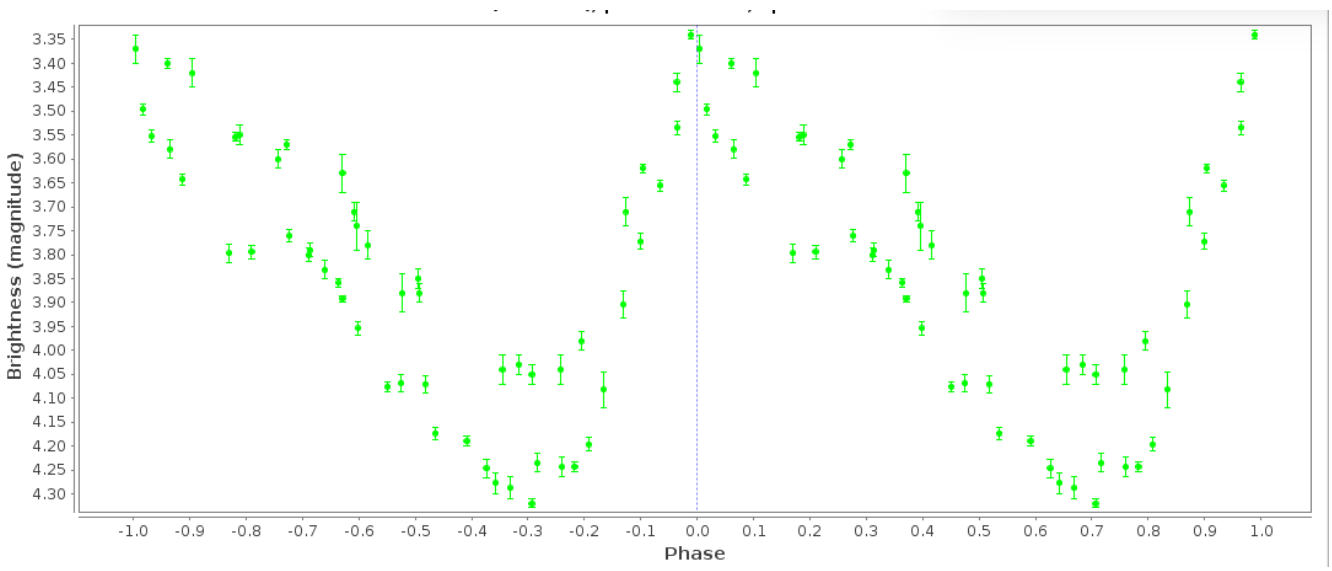
22 The four stars are, respectively, 000-BFX-121, 000-BFX-117, 000-BPD-369, and 000-BFX-126.
23 SIMBAD and VSX disagree as to its magnitude. I here use the SIMBAD value.
24 This includes tricolor red and blue to R and B.

Eta Aql

Consider the V band light curve:



Two observers are involved and it's hard to interpret what is going on. The star is a Cepheid, so a phase plot is in order.



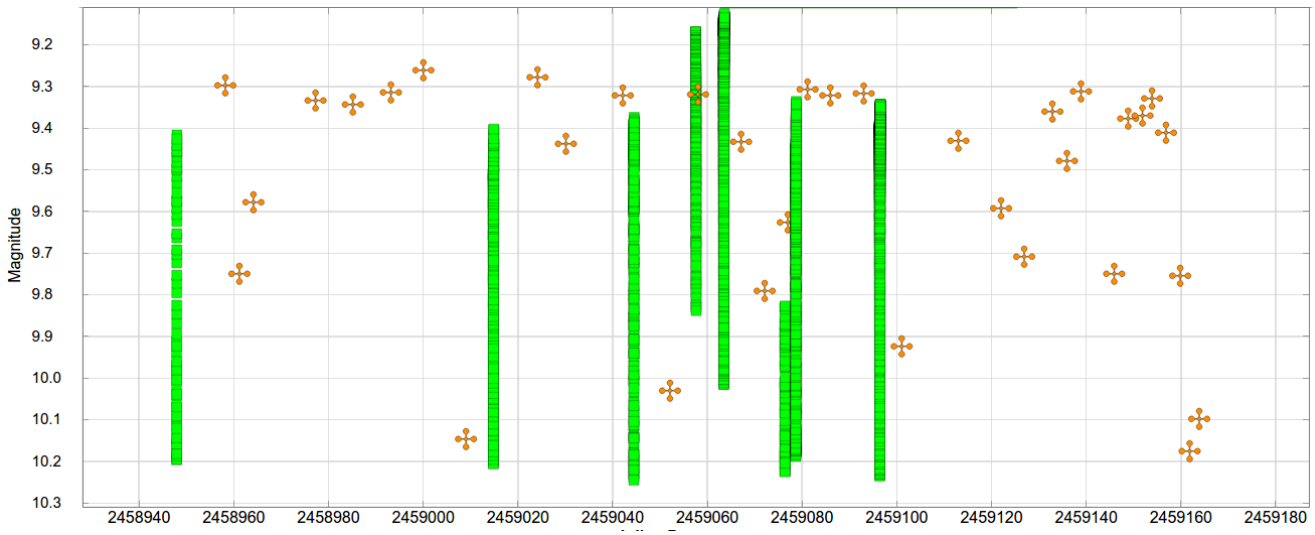
Now the situation become clear. We have another dual trace, with one observer (J9J) about 0.2 brighter than then other. Who is right? VSX says that eta Aql peaks at about V=3.5, and J9J is going about 0.15 brighter than that, so I'll call him out. Why he is too bright is unclear. His comparison is a poor color match for the variable [Δ(B-V)≈0.9]. It is iota Aql, which took some work to figure out. The chart he specifies is a visual-only chart from the 10 star tutorial. The "44" comparison star he uses has no counterpart on a VSP chart.[25] I had to go to a physical star atlas to divine the indentity of this star. I don't think we want people using the visual charts for photometry.

Since the LCG does not support phase plots, VStar is a sometimes a necessary diagnostic tool.

25 That is, no star for which magnitudes and an identifier are available.

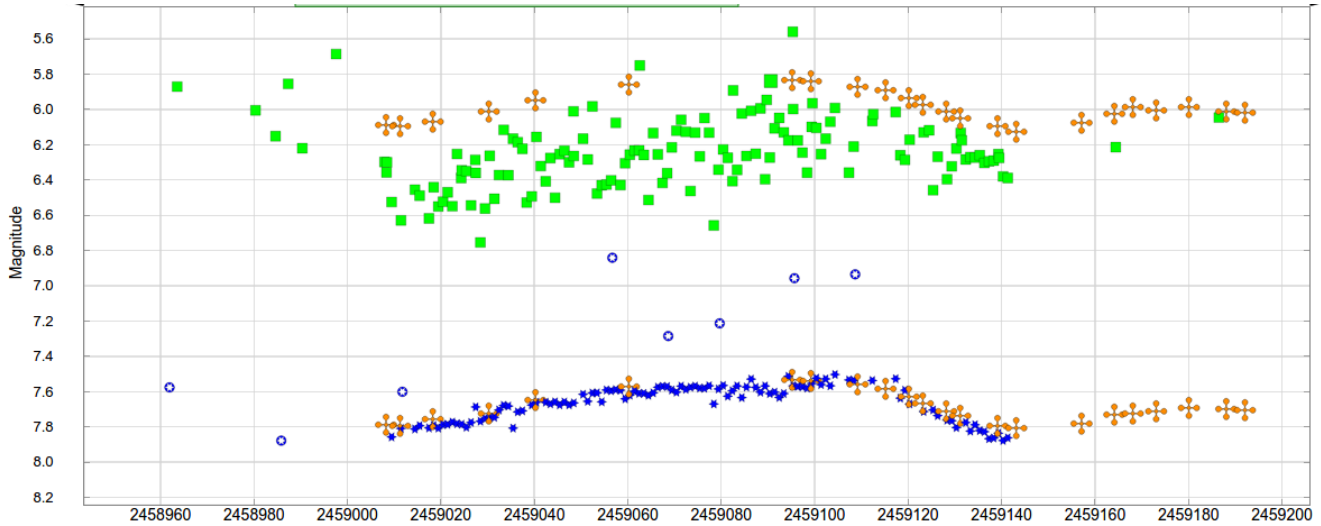
OO Aql

OO Aql is a rapid eclipser (12 hours). Observer R2D is highighted below. His scattershot data seem to serve no purpose. Curiously, at one point in the past he followed an entire eclipse and got a nice light curve.



XY Lyr

Below, PEP observer SS5 is highlighted:

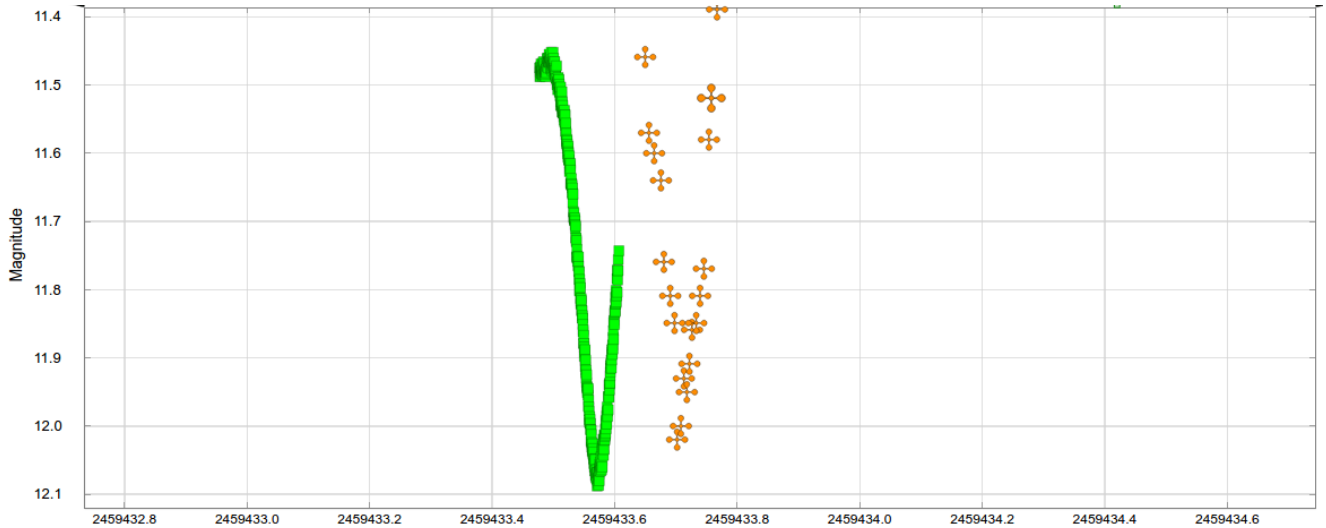


The bulk of the other B&V points are S4E. His B data look fine but the V points are systematically and erratically faint. I will venture that he is saturating in V band; the degree to which he is faint depends on how close to the linear limit he is operating and the extinction on any given night. His check-minus-comp magnitudes look reasonable, but the variable is almost three magnitudes brighter than the comparison.

The (bright) TB points are Y6Q with a DSLR, again (see XY Lyr/VV Cep, above).

BT Vul

Observer F5R is shifted in time and magnitude with respect to B66.

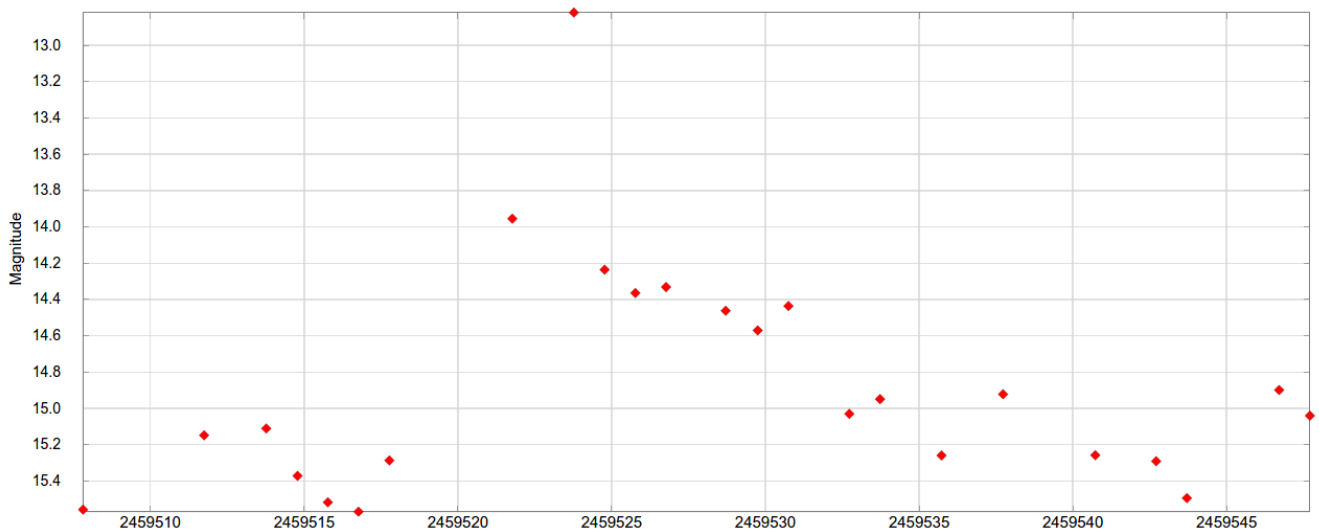


F5R highlighted

If we assume that F5R's low point corresponds to B66's lowpoint (not a robust assumption), then F5R's reported observation times are too late by about 3½ hours. This problem was discovered in a phase plot, where earlier data from observer L77 could be seen in good agreement with B66. In an ordinary light curve you must zoom in very close to see this anomaly. [Note from Brian Skiff: use of local time in place of UTC is a common error (though that doesn't seem to explain this particular situation).]

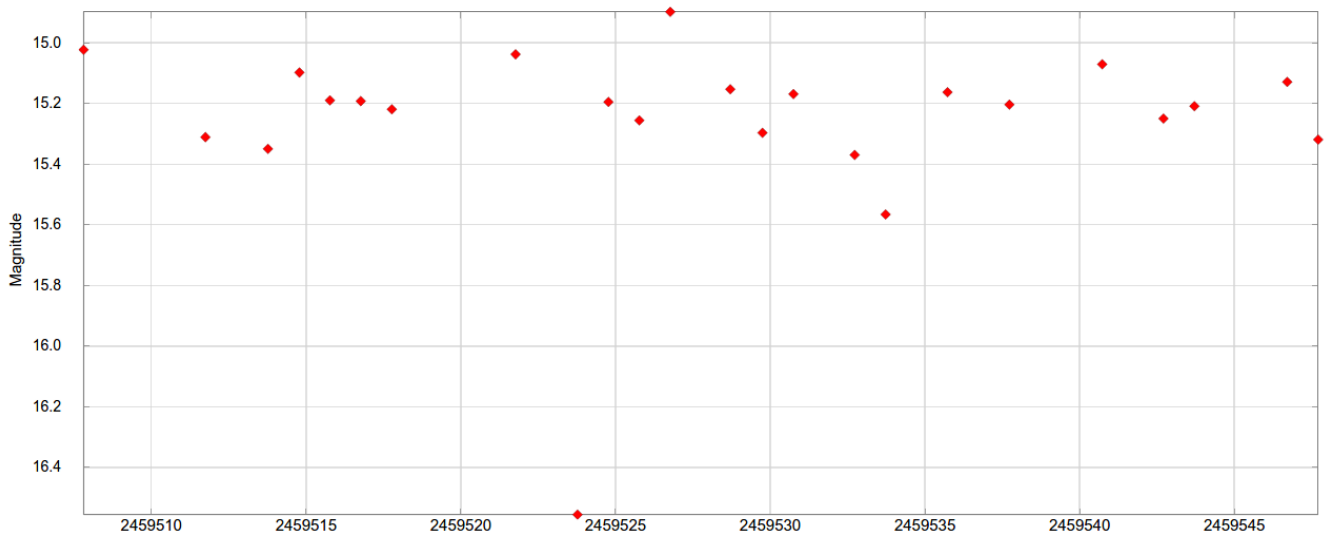
V677/681/1159 Ori

These stars were captured by W5W in the same R band CCD frames as part of a multi-day sampling. Below is V1159 with a bright outlier on 2459523. [This is November 5, 2021. The adjacent data points are from the 3rd and 6th.]



V1159 Ori with bright outlier

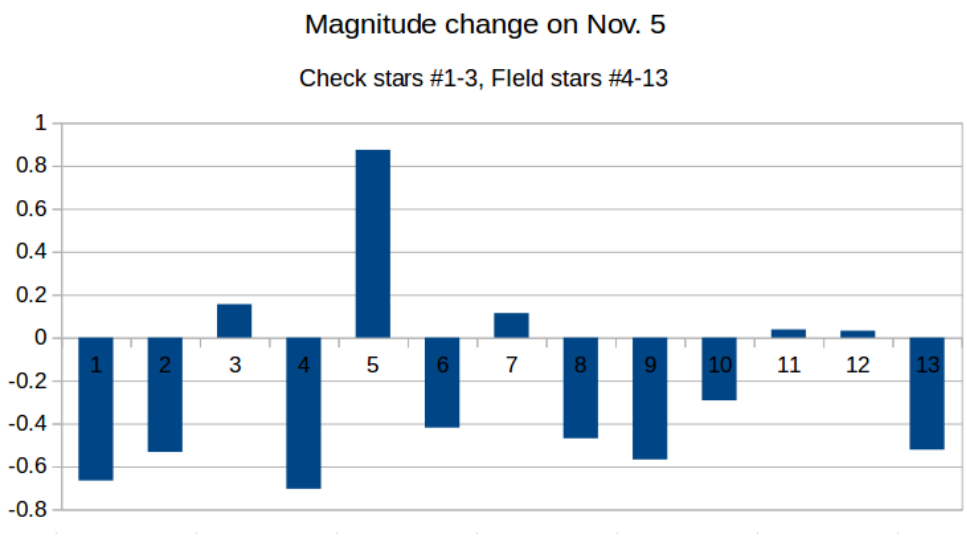
From the same frame, V681 had an equally discordant *dim* outlier.[26] It seems highly unlikely that both of these stars could behave so erratically at the same time.



V681 Ori with dim outlier (in same frame)

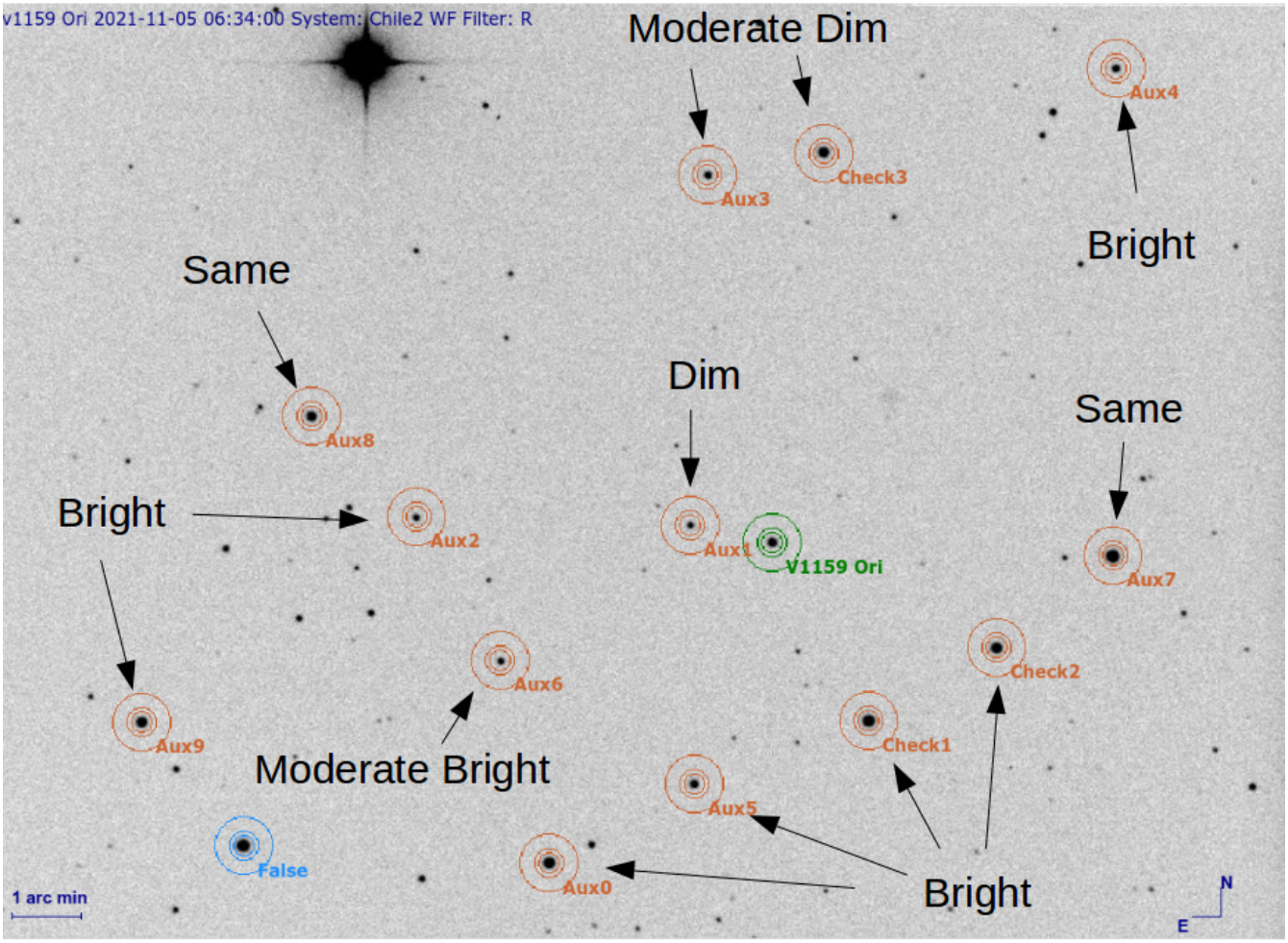
Although the comparison was marked as "ensemble," the reductions were actually made against a single star.[27] A check of the FITS history keywords revealed that the frames (from SLOOH) were corrected for bias and dark counts, but were not flat-fielded (!). V681 is rather dim: its SNR on the nights on either side of 2459523 are only about 25. It is plausible that the star got unlucky in the unflattened field on the discrepant night and lost too many counts.

The bright V1159 is harder to explain. I assembled a group of thirteen check stars for use on 2459523 and the two bracketing nights. For each star, the average of the bracketing magnitudes was subtracted from the magnitude on 2459523. Most of the stars brightened on that night, but not all and none to the extent of V1159 (-1.3).[28]



26 V677 had a modestly bright outlier.
27 The comparison star was actually mis-identified, but that just introduces a wholesale shift in the light curve.
28 The first three stars in the diagram are AAVSO reference stars (comparisons), the others are unknown field stars.

The distribution of my thirteen check stars is shown below (frame from November 5).



"Bright" or "dim" means a change of at least 0.4 magnitudes. "Moderate" is a change of 0.1 to 0.4. "Same" is < 0.1. The field is not far from the center of the frame. The blue star is the comparison. "Aux" stars are unknown field stars.

Z CrB

While examining XX5's DSLR data for this star I found oddities in his transformation coefficients (listed in the observation comments). Below is a table that shows epsilons for B, V, and R on nine nights (for a variety of targets).

JD→	**2459303**	**305**	**314**	**327**	**331**	**365**	**366**	**380**	**381**
εB	0.390	0.4083	0.439	0.390	0.390	0.4083	0.361	0.390	0.4083
εV	-0.135	-0.1222	-0.148	-0.135	-0.135	-0.1222	-0.140	-0.135	-0.1222
εR	-0.299	-0.3060	-0.379	-0.299	-0.299	-0.3060	-0.383	-0.299	-0.3060
group	**1**	**2**		**1**	**1**	**2**		**1**	**2**

When I first looked at these numbers I thought that XX5 was establishing his coefficients nightly. But then I noticed two groups of duplicates, here labeled 1 and 2. It seems impossible that the BVR coefficients for 2459303 (group 1) could exactly repeat on 327 and 380 while being different in-between. Likewise for the coefficients of 2459305, 365, and 381 (group 2).

XX5 may very well be establishing transformations on a regular basis, but there are clearly errors in the metadata, no doubt due to manual editing of the comments. This likely also explains one epsilon labeled as "TR_BV" when it should have been "TR_VR."[29]

Additionally, one of XX5's V data points for Z CrB was reported as R band.

UCAC4 687-086223

Looking at P31's BVRI from 2459451 to 2459548 I noticed something odd in I band. Closer inspection showed high uncertainties (median 0.359) from single-comparison reductions. We've already seen problems with high uncertainties, but there's a different angle here. A few reductions were done with ensemble and showed far smaller errors (median 0.088). I don't see why this should be. The single comparison is much brighter than the target, so its own uncertainty can't be adding much to the total error budget. How can an ensemble do so much better?

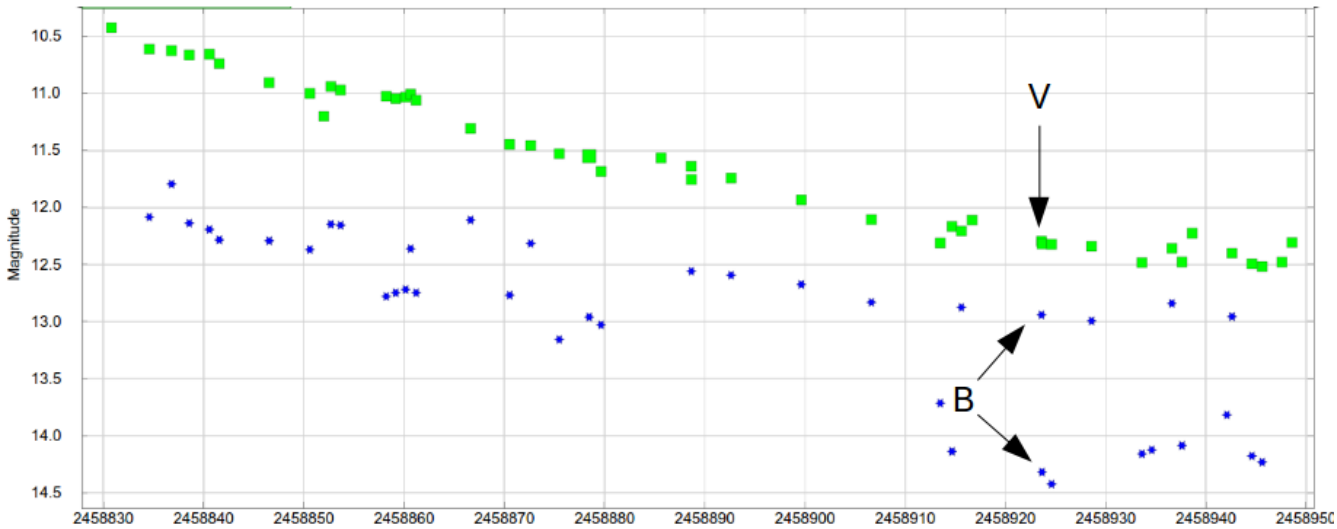
At least, I *think* the comparison is much brighter. It is identified only as "110" rather than the nine chararcter AAVSO ID.[30] There might be another 110 star that is much fainter in I band. Unfortunately, if I try to recover the list of available comparisons by plugging the reported chart ID into VSP, the operation fails on account of too many stars in the field-of-view (however big it happens to be). This is the second time I have run into this problem in the course of drafting this note. The "timeout" value that VSP uses to give up on overly-dense plots should be revisited.

Also, there appears to be an inconsistency in the way VPhot reports the check star magnitude. With a single comparison this was a negative value but it was positive with an ensemble.

29 Similar to M2B on QX Cas.
30 On a chart with an arbitrary radius 60 arcmin.

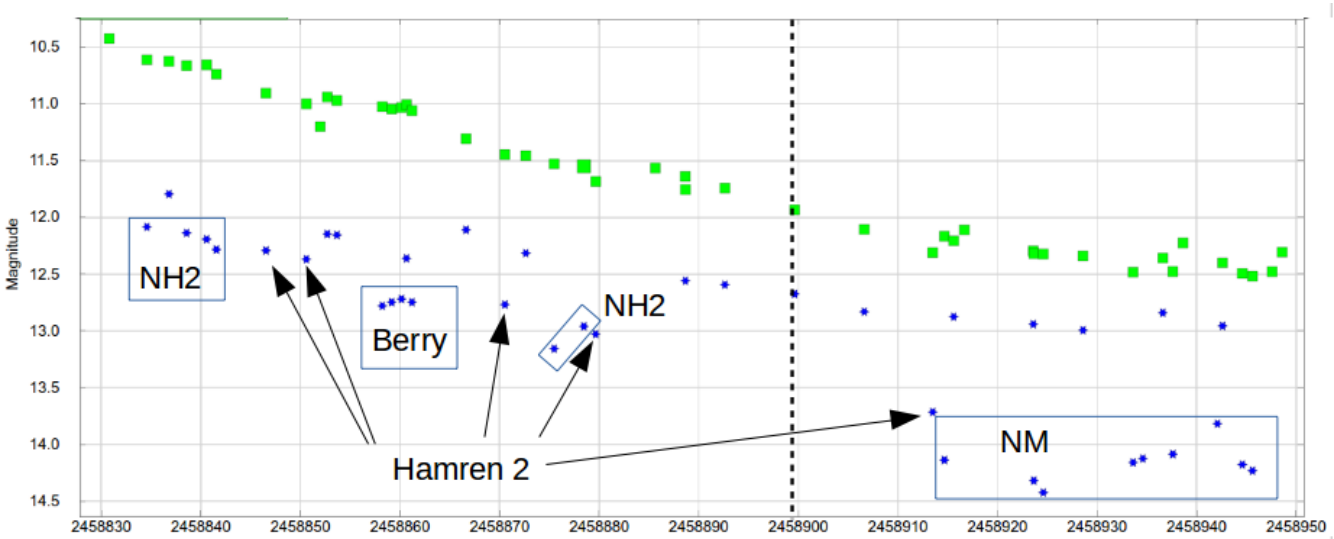
S Ori

For VV Cep we saw a scenario where to observers agreed in V band but disagreed in B, probably because one of them was reporting untransformed TB in connection with an O9 comparison star. For S Ori, M7M and J3T are in a similar situation, though with CCD data. J3T has the dim B points below, all taken with BSM instruments.



Overlapping V points and discrepant B points on JD 2458923 arrowed.

The two observers both took data on 2458923, their V points closely agreeing but differing by over a magnitude in B. At the beginning of the above light curve, J3T is much closer to M7M than he is at the end. His data were taken through four different BSM units (Hamren 2, New Hampshire 2, Berry, and New Mexico).

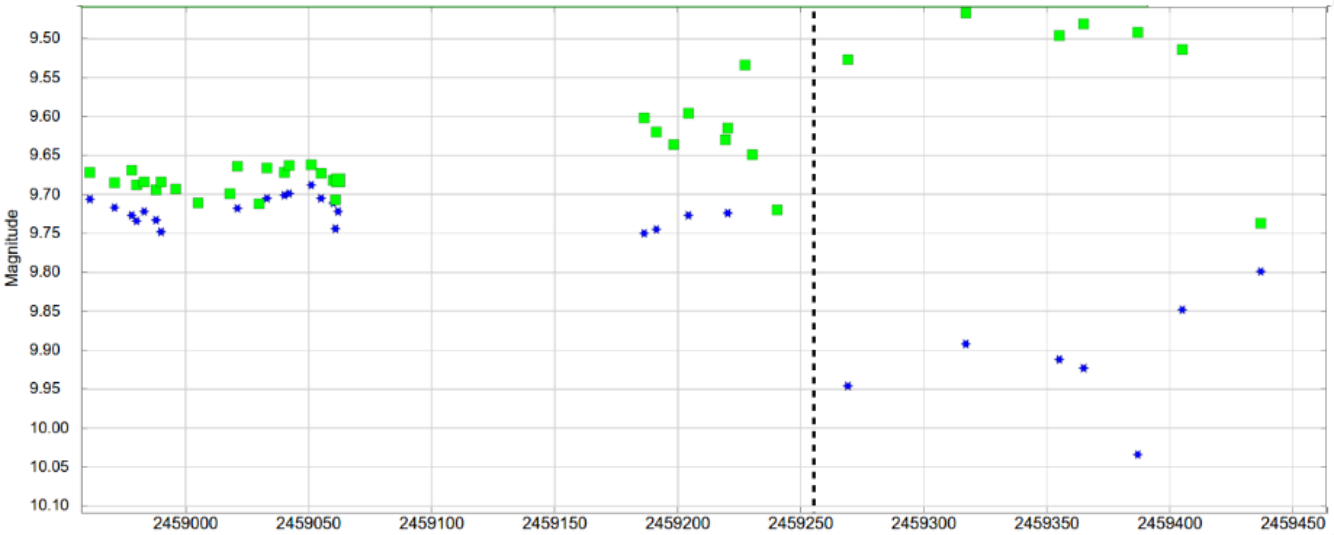


J3T B band marked; M7M points are brighter. J3T B data to right of dotted line are transformed.

J3T's highly discrepant data data at the end of the light curve are all transformed, while the points in better (though not great) agreement with M7M are untransformed. Very curious. The reductions were all by VPhot.

HD 106793

BV magnitudes from HJ5 and PK9 are shown for this GCAS star, whose B-V should should be small.[31]



HJ5 data to left of dotted line, PK9 to the right.

HJ5 is having some difficulty towards the end of his own light curve, but PK9 (following) is mostly way out of line. The PK9 V points are too bright and the B are too dim. He is using an ensemble of at most five stars, each of which is much redder than the variable (B-V=1.117...1.375). Transformation is not being applied.

This is yet another situation where an anonymous ensemble of comparison stars stymies analysis of the problem. There is great faith among some observers that ensemble reductions give results that are superior to those from a single comparison star. I don't believe, however, that anyone has presented actual evidence showing how ensemble photometry–as actually *practiced* at AAVSO–is superior. Even if the identities of the ensemble stars were known, it is not clear that any conclusions could be drawn about this or other problematic examples if the CCD frames were not also available.

S2 0199+2B224

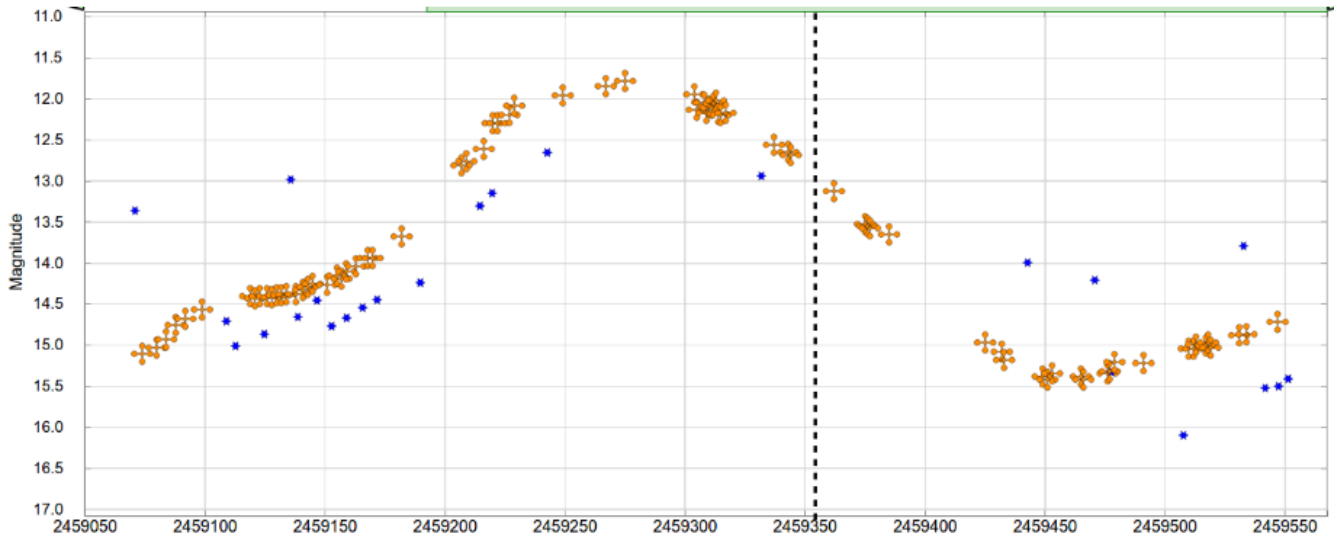
Something peculiar is going on with observer P9H circa 2459500-560. He is primarily shooting quartets of SG, V, SR, and SI (a single set of four on each night he is active). There is nothing untoward in the data, themselves, but the nightly timing is very strange. He is waiting 15, 20, 30, 40, and even 50 minutes between CCD frames. Why? [He's not taking data on other stars in the meantime.] It's as though he sets up one exposure to run, then walks away from the telescope. Are his reported times actually correct?

His Sloan comparison magnitudes presumably come from APASS, but there's no way to tell.

31 Thanks to Sebastian Otero for help on this one!

S Cep

Another B band example.[32] Below, observer HJ5 provided most of the data.



HJ5 highlighted

But is he right? To the left of the dotted line are a number of fainter points, and they were supplied by experienced observers. Our current suite of metadata does not include an indication for second order extinction, so it is possible that this is a factor, but it's hard to see how it could explain the ½ magnitude difference that is often evident.

The bright data points all come from observer LL5. His other observations on the same nights, if not perfect, are reasonable. As an aside, his three bright points to the right of the dotted line are apparently all-sky photometry, which was the approach he used on other stars those same nights.

The three dim points at far right were gathered by UR2 using a Baader RGB filter set. The instrumental magnitude of the variable is included in the comments, and it does not make sense in regard to the comparison. The standard magnitude difference between the variable and the comp is roughly 1½ but the instrumental difference is only about ½.

The remaining dim point, from TM2, is the faintest from HJ5. I can't say why it diverges, but the observer's "software" metadatum is curious: "MAXIMDL + SEXTRACTOR + PSFEX + EXCEL." Why is he using so many programs, and is he using them properly?

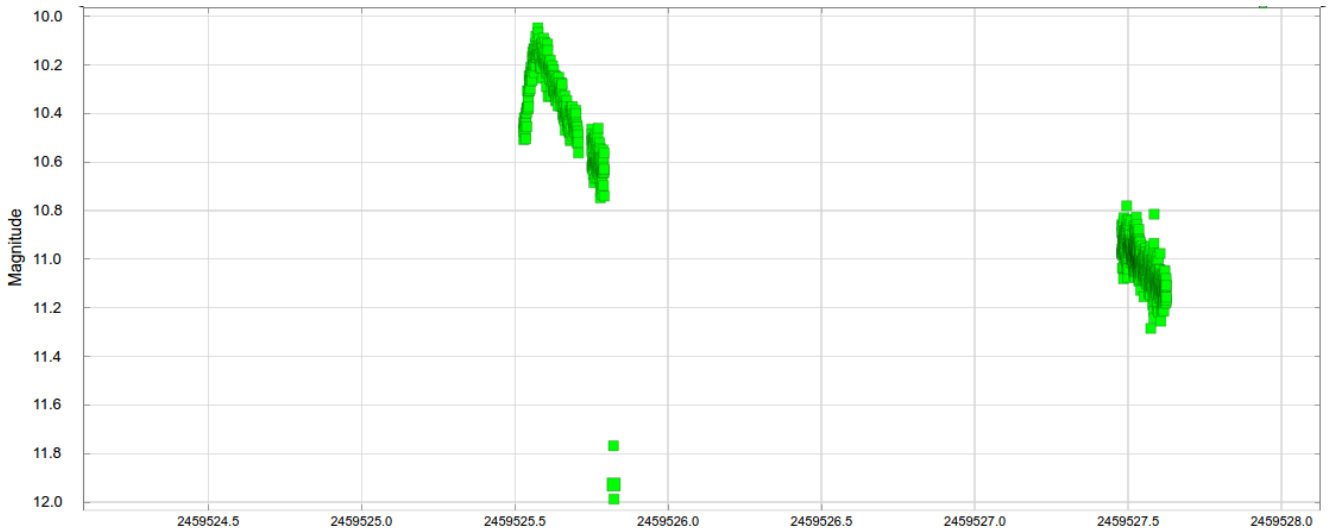
Quick Aside, 2

On 2459558/9, observer K0N was reporting U band data that were surely V band, in fact. [RX PUP, T Hor, TT Ind, etc.] This was presumably a typographical error. Similarly, in the fall of 2021, observer JF2 was reporting U band fainter-thans for LS And in DSLR data (that can't have U band).

32 Corresponding V band data, again, looked good.

XX And

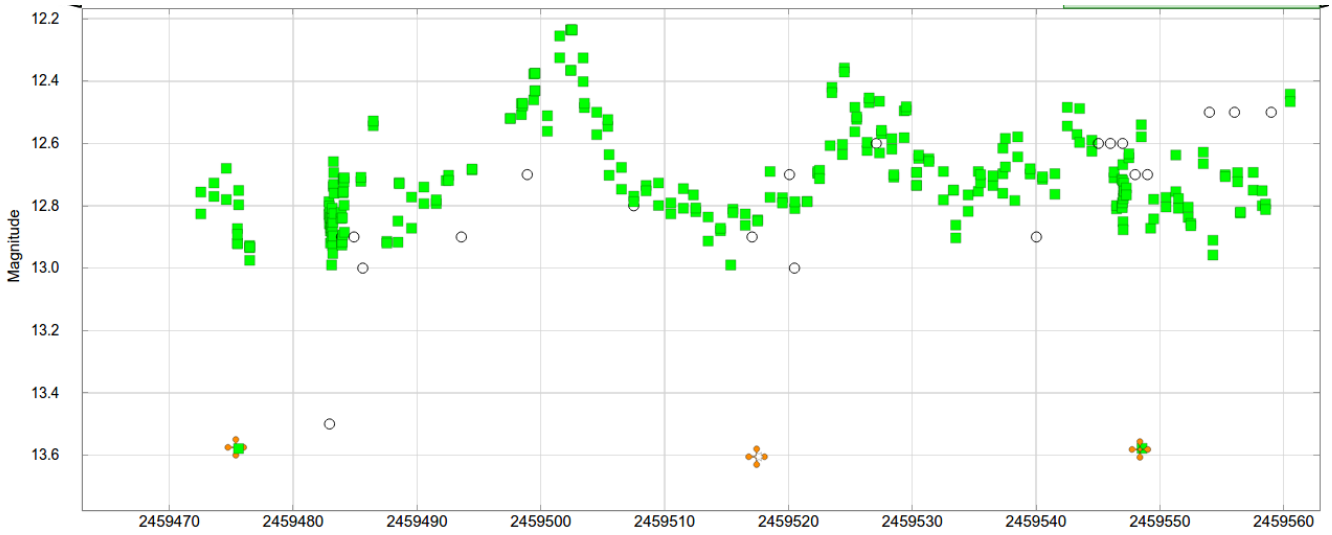
YW4 takes timeseries on this star. His data for 2459522 includes three rather faint points. The outliers were taken at a reported airmass in excess of seven, but this is inconsistent with the observer's location and reported time (unless he's using a remote observatory at a dramatically different longitude). A bad clock setting?



YW4 with three faint outliers

VY Scl

Observer U5K has three data points that are faint. What's more, these nearly-constant magnitudes seem incongruous with variation evident in the larger light curve.

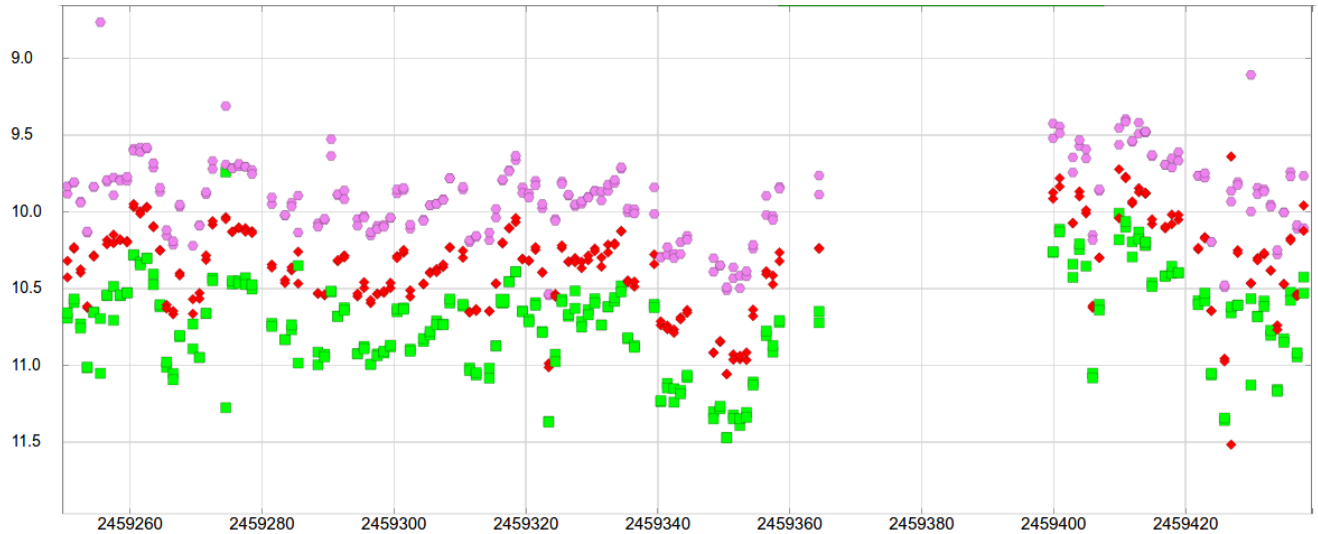


Observer U5K highlighted.

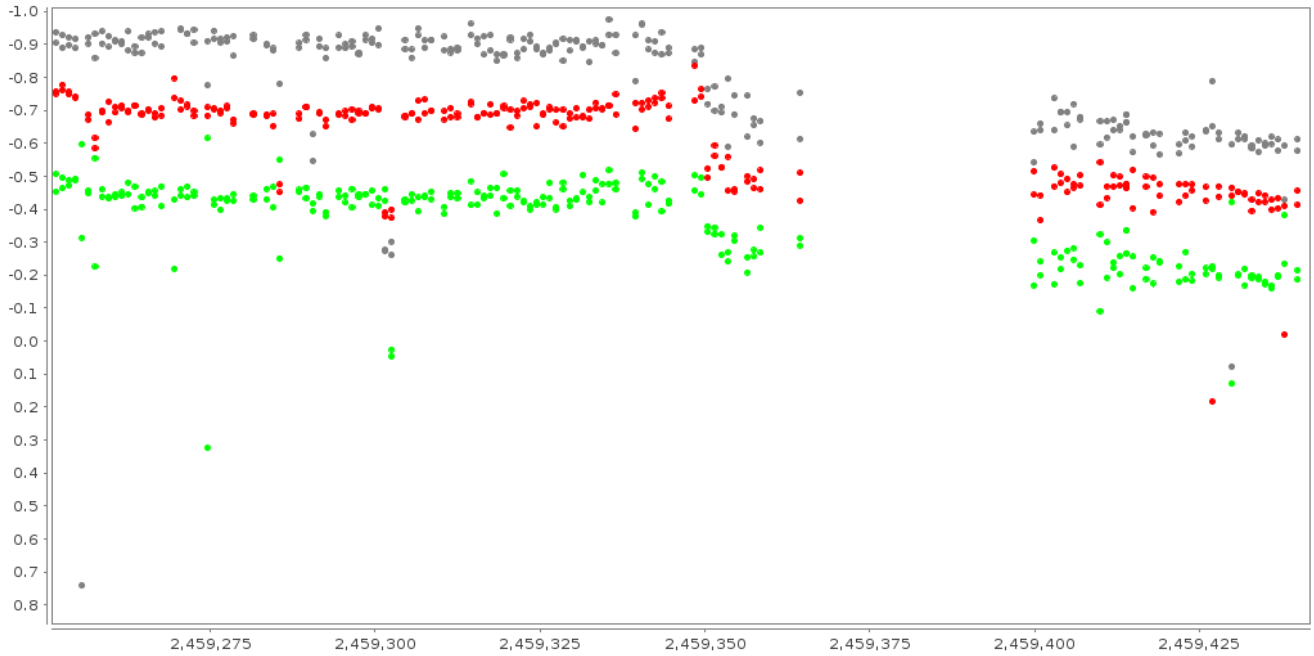
As you can just make out, the first and last of these points are accompanied by a second measurement (from F1L, apparently collaborating with U5K). U5K reduced against a single comparison, while F1L used an ensemble to arrive at essentially the same result. I'm guessing that they both misidentified a constant star as the variable.

T Ori

Observer TT3 clearly has some I band outliers, below.[33]



He also has R and V outliers that are hard to see in the plot. TT3 includes the reference magnitudes for the comp and check in his comments, and populates the comp and check instrumental magnitudes. Below is a plot of instrumental(check-comp) minus reference(check-comp) for the three bands.



I band color has been changed to grey for better visibility. R and V have been shifted downward. [VStar plot]

You can see where TT3 changed his check star, and also where the instrumental deltas are incompatible with the reference deltas, indicating outliers. This kind of plot is a potentially powerful diagnostic tool.

33 The observatory is remotely-controlled, so atmospheric or instrumental problems may have gone unnoticed.

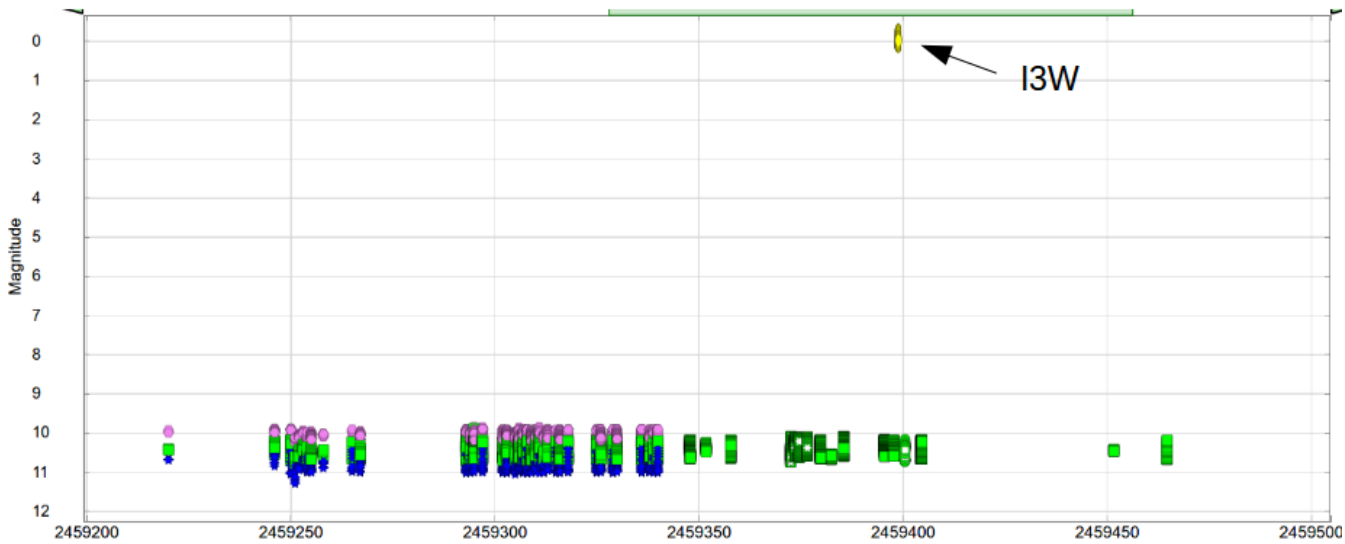
MU Cam/BI CVn

Observer S4W reports interleaved timeseries for these stars circa 2459604.5. Given that the targets are almost 100º apart in right ascension his mount would need a remarkable slew rate. Either the observer has two telescopes (unlikely) or he has the date wrong for one or both stars.

DY Her

Observer I3W has a timeseries taken through a green filter. He reports it as band "N/A" and apparently uses an arbitrary reference magnitude for the comparison, putting his magnitudes far off from other observers. The AID has provision for "G" filters–what guidance is given for reporting data in that band? Given that we do not, in fact, have any reference magnitudes for this band, do we really want data from this filter that has not been transformed to a photometric band? And what guidance is given for reporting G versus TG in this case? Is TG strictly for DSLR or is it intended for CCD green filters as well?

Ironically, the timeseries looks good, but his chioce of reference magnitude badly distorts the LCG display for the star.



I3W timeseries at top circa 2459400.

Wasp 11, 35, 52

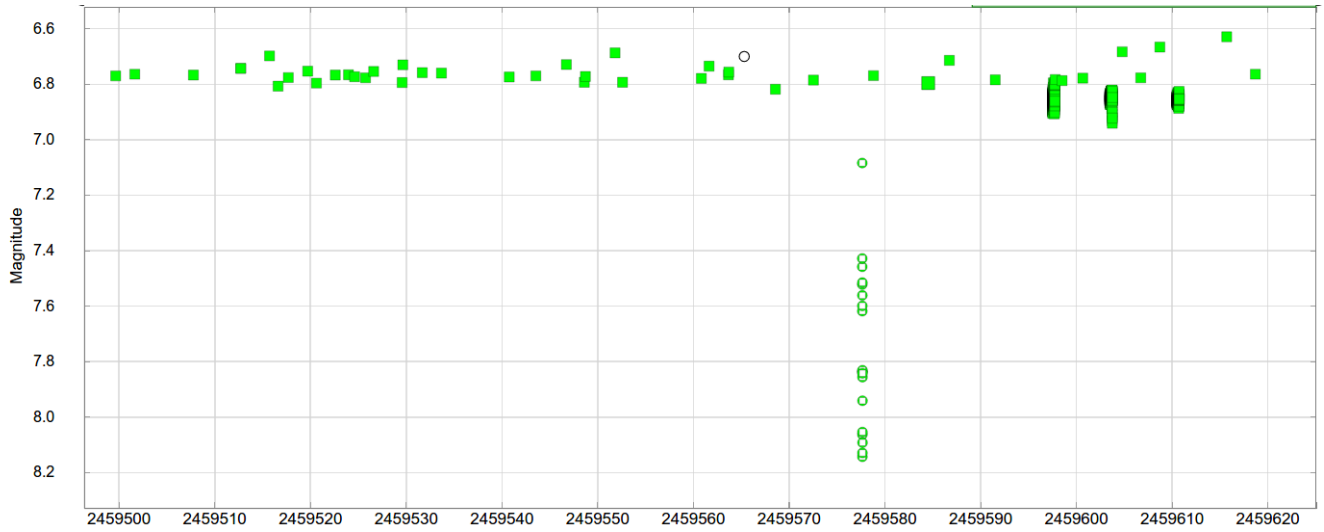
Observer D7Q is using "synthetic" flat and bias frames to calibrate his images. We should decide if such calibration is adequate for our purposes (I believe the technique is intended for photography, not photomertry). If yes, we should specifiy just what procedures should be followed in the synthesis.

RY Dra

Observer T9L comments that his sky brightness is "Bortle 8": the next-to-worst level in light pollution. What guidance do we give regarding such bad conditions? [One of his data points is way off.]

V1229 Tau

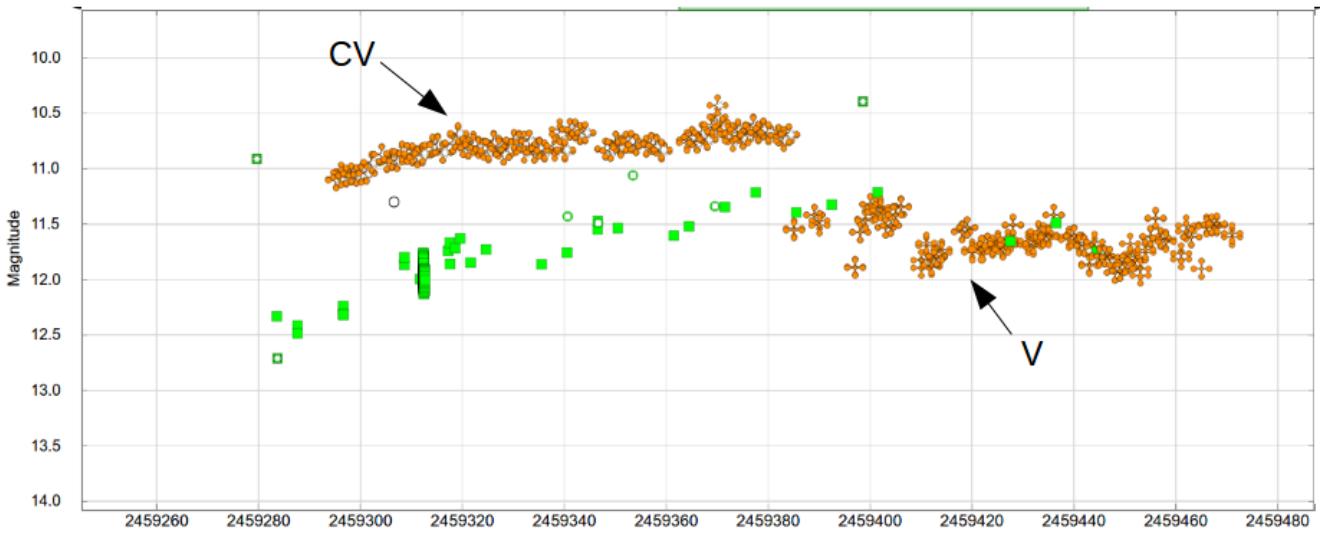
Observer L5T reports a widely divergent timeseries. Other examples of this type have been given, but I want to emphasize that this kind of problem is common among DSLR observers. He is using NOVA-PATROL software to reduce the data, a package I have never heard of. His comments include cryptic notes such as "DR=0D00M01.1S SNRN=9."



L5T timeseries circa 2459577.

RT Cru

Observer TT3 reports magnitudes in CV, then in V. The two data streams are discordant even though TT3 is using the same comparison star for both. Looking at the instrumental magnitudes for the comp and check, it appears that he has the right reference stars and the comp color is a good match for the variable. What is causing the big shift in CV?



TT3 (highlighted) in CV and V. V data consistent with other observers.

The above examples were gleaned by me, pawing through the AID. I will now turn to problems that have been noted in the professional literature.

P Cyg

P Cyg was the subject of a 2018 research paper by Michaelis, et al.[34] They were searching for periodicity due to a postulated companion.

I quote:

> *The accuracy of the AAVSO data is≈0.01 mag in the V band. This translates to a precision of about 1% in the flux measurements. However, at most of the nights there are multiple observations, taken by different observers. The average of these observations increases the precision to 0.1–0.5%* [assumes the scatter is statistical]. *...for the companion MS star we take the most favorable values from (Kashi 2010) to allow detection T2= 19000 K and L2= 1500 L⊙. Calculating black-body emission, the expected ratio in the intensity in the visible is≈0.3%... We therefore conclude that only for optimistic parameters the AAVSO data is of about the required precision to be used in our analysis. We nevertheless proceed with the analysis with the hope of detecting a binary signal* [it was not found]. *The other observations we use are of much higher quality and can therefore be used with no concern.*
>
> *.... We hope that AAVSO observers and other campaigns will continue to document the photometric variation of P Cyg with an increasing precision, such that this exercise can be repeated in a few decades with a longer duration of observations.*

The date range in question is 1972-2018. The earliest CCD data are 1994; the earliest DSLR data are 2009. PEP covers the entire range. The median error for the PEP data is 0.003, which seems good enough for the analysis described above. The median error for imaging data is 0.013, not nearly good enough.[35] It would be interesting to find out if the authors were aware of this division. It would also be interesting to know if AAVSO noticed the call for better measurements.

Barnard's Star

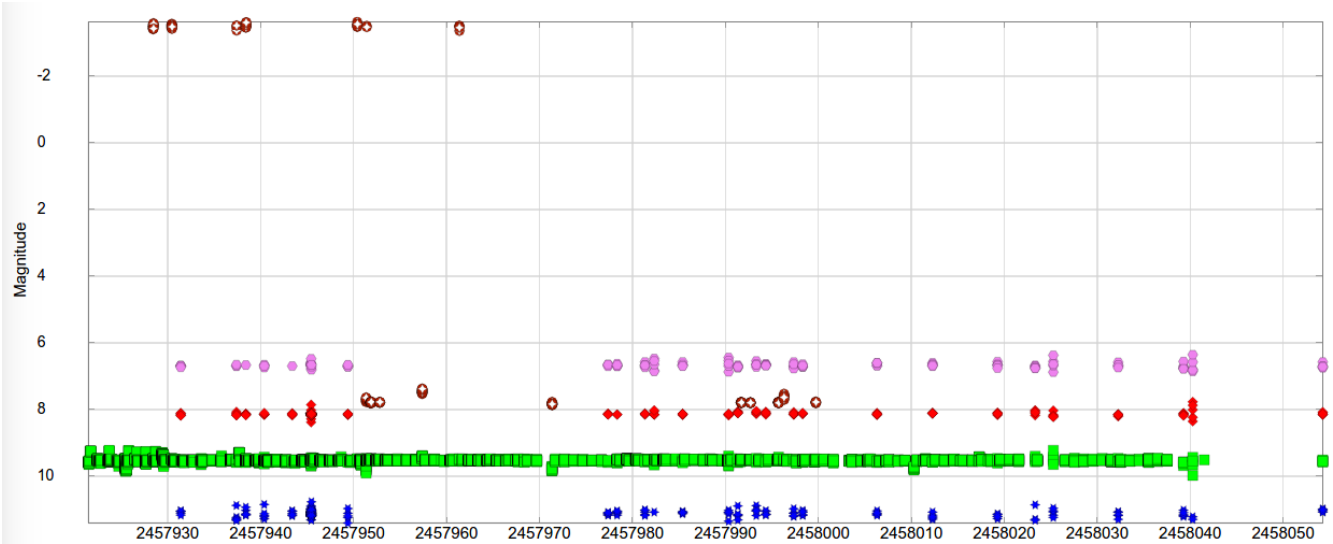
Barnard's star (AUID 000-BDB-728) was the subject of a campaign in 2017. The data were subsequently used in a paper by Toledo-Padron, et al. (MNRAS 2019).[36] I quote: "*...we requested support from the AAVSO (American Association of Variable Stars Observers) and issued an AAVSO alert with a call for photometric follow-up from observers. The answer was enthusiastic, with more than 8000 measurements in the BVRI and Hα filters for Barnard's Star uploaded to the AAVSO database from 14 observers in eight countries... About 75% of the observations/acquired exposures (or half of the datasets) had great quality and could be included in the analysis..."*

34 https://arxiv.org/pdf/1806.00769.pdf

35 Data with no specified errors not included. Be aware that the PEPHQ data reduction program could, for very consistent samples, return an error of 0 (this has been fixed). Some DSLR data were submitted as passband "Vis" and were not included since the researchers searching for V data would presumably not have found them.

36 https://arxiv.org/pdf/1812.06712.pdf

It's great there were so many good data points, but some 2000 observations were unusable. The light curve is below.

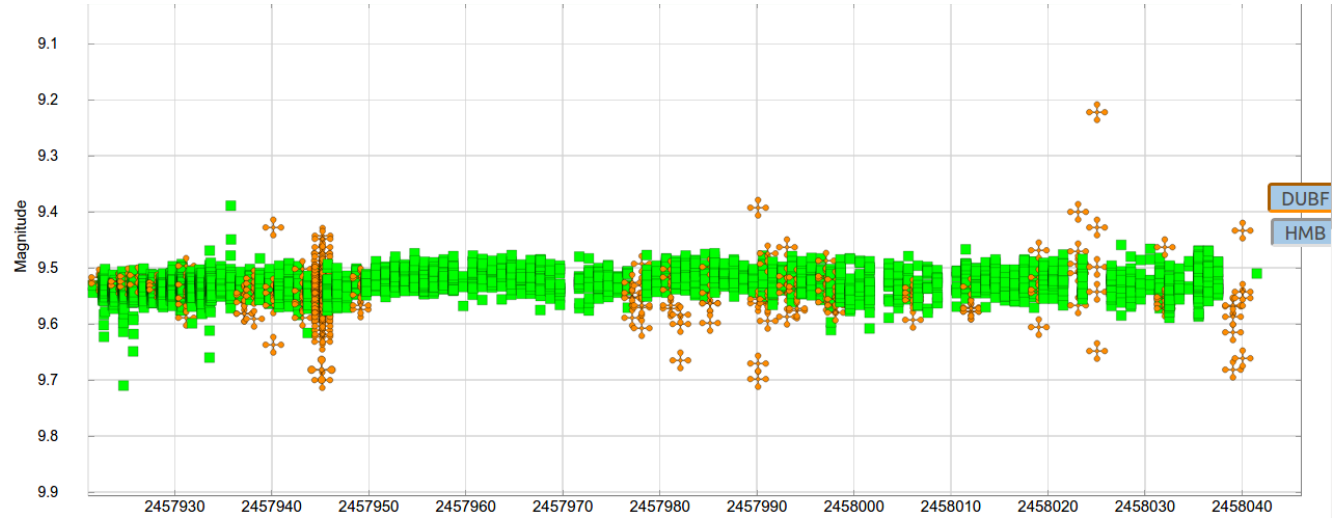


Barnard's Star 2017 campaign. Hollow brown dots are hydrogen-alpha.

The most obvious problem is a line of Hα magnitudes at upper left. They all come from G4K and are about eleven magnitudes brighter than the Hα reported by two other observers.

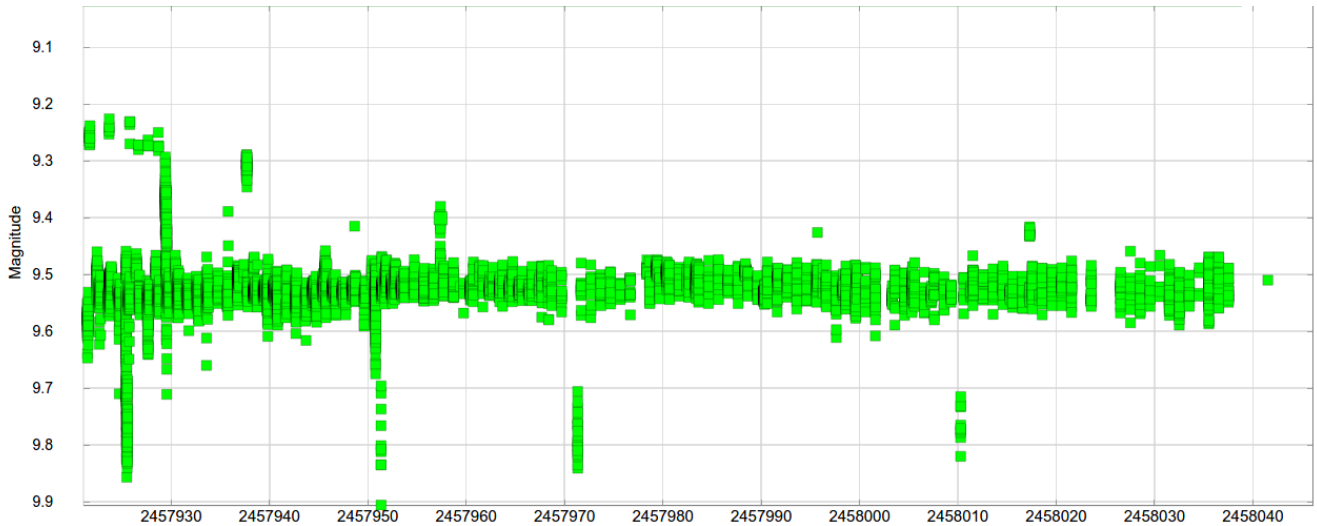
The alert for this campaign included a dedicated chart with comparisons. Observers identify their comparisons with the mnemonics from that chart, but the data records make no mention of the chart itself. Researchers not involved in the original campaign would have no way to find the chart, tucked away on the AAVSO website. The chart, in any event, gives no comparison magnitudes for I band or Hα.

Observer U81 supplied all of the BRI photometry, as well as some of the V measurements. His median uncertainties were **I**:0.038, **R**:0.018, **B**:0.062, and **V**:0.024. Given that the purpose of the campaign was to find exoplanets, these high uncertainties seem to disqualify his data. Below is a V light curve of U81 and TT3. I believe that TT3 is a reliable observer, and his data are shown in green. U81 data are highlighted, and there are definite problems beyond the uncertainties.



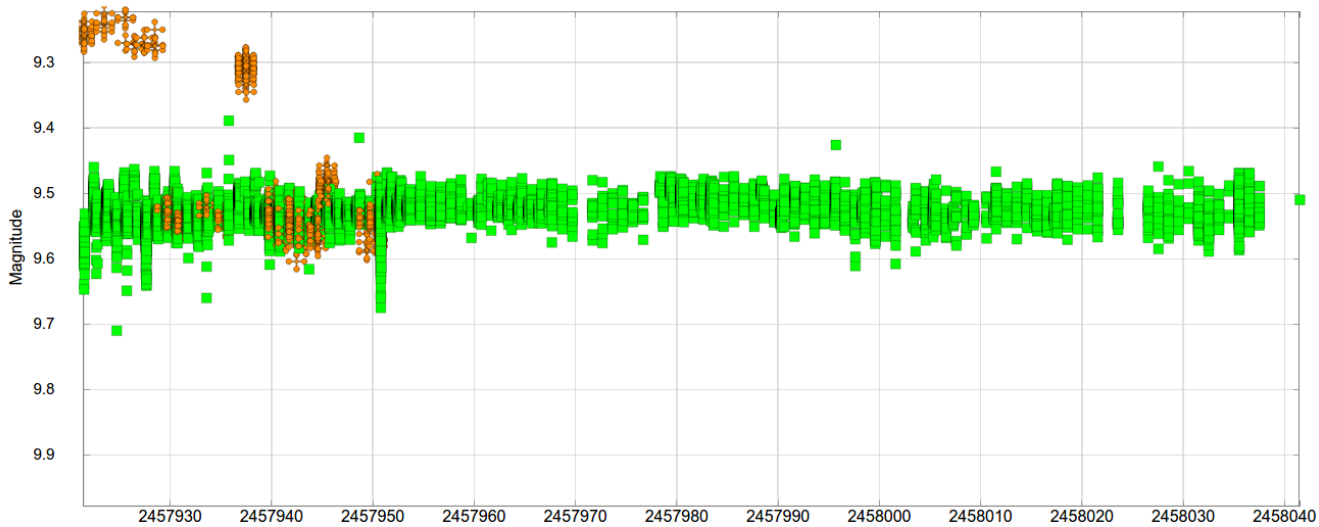
V band TT3 in green, U81 highlighted.

If we now dispense with U81 and bring in all the other observers, we see discrepant timeseries that are vertical excursions away from the central light curve. They are from observer U5K.



Non-U81 V data. U5K diverges from norm.

I don't, offhand, see a reason for U5K's problem, but he and U81 together account for ~1300 questionable observations. Dropping U5K, we have:



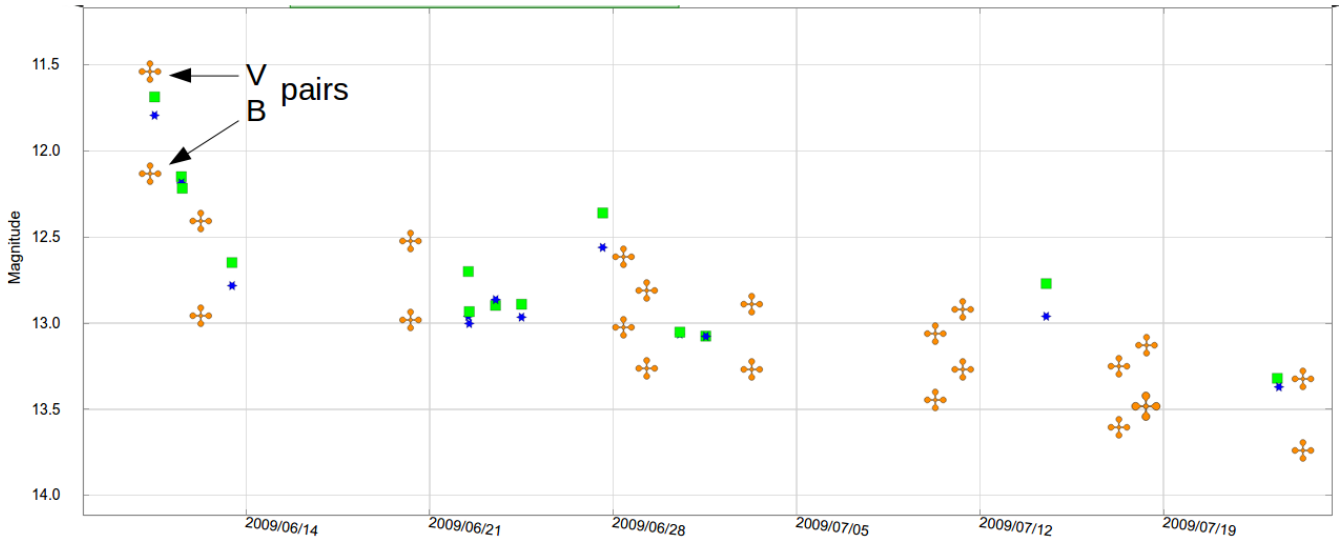
KU9 highlighted. Discrepant timeseries at ~2457950 is F1A.

Observer KU9 has both reasonable and unreasonable data and his median error is 0.038. I can't spot an obvious cause for his elevated magnitudes, but I note that about halfway through his period of contributions he stopped reporting airmass and he later switched to ensemble reductions, which he wasn't supposed to do[37] (observer P0H also made hundreds of ensemble reductions).

37 The campaign announcement specifically said, "Please use only these charts and comparison stars...". It is not clear that the author noticed the change in reductions.

Nova Cen 2009

In 2019, Izimu Hachisu made extensive use of AAVSO light curves in his analysis of 32 novae. His first paper[38] noted problems with data for V1663 Cen in June 2009. Below is a portion of the BV light curve.

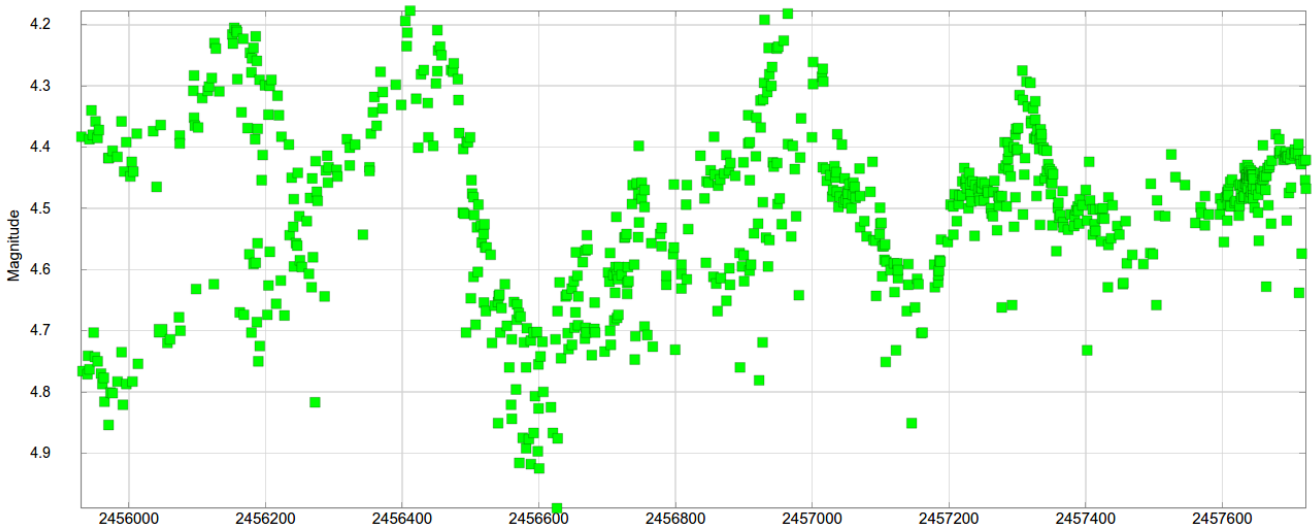


L4T's nightly BV pairs highlighted (V points brighter than B)

Pairs of BV data points for observer L4T are highlighted above. Hachisu rejected the BV from other observers, whose B-V values are notably different from L4T, and which did not agree with data from other sources. Hachisu also notes problems in other AAVSO light curves with observers not reporting uncertainties, which hindered his analysis.

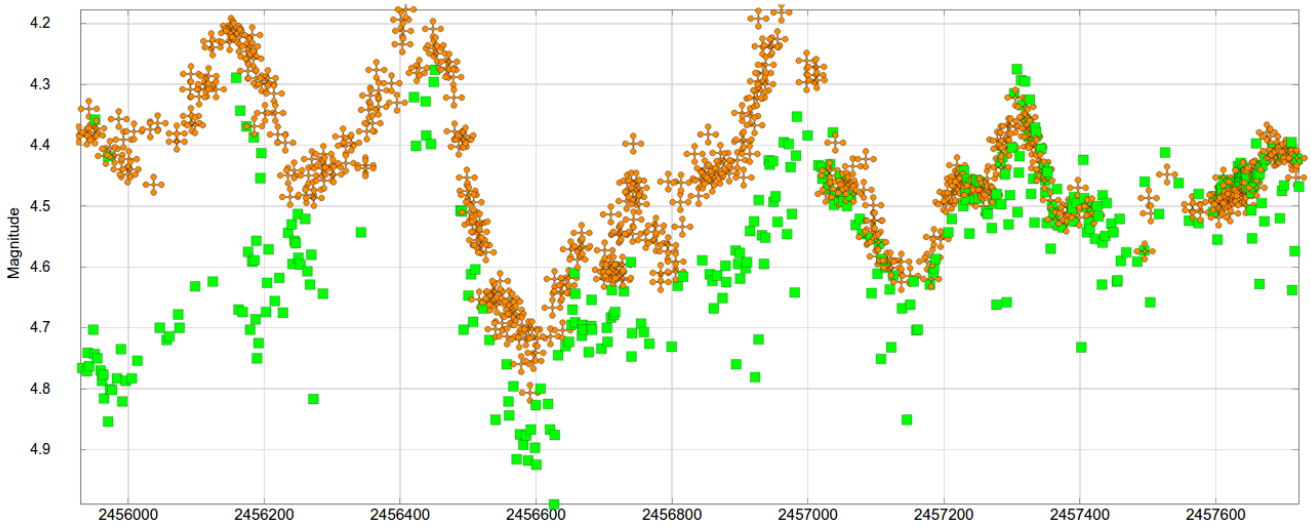
Rho Cas

This star is a subject of the 2017 "DSLR Notes" in Appendix A. The very data illustrated there were picked up by M. Kraus in a 2019 MNRAS paper (https://arxiv.org/pdf/1812.03065.pdf):



38 https://iopscience.iop.org/article/10.3847/1538-4365/ab1b43/pdf (ApJS)

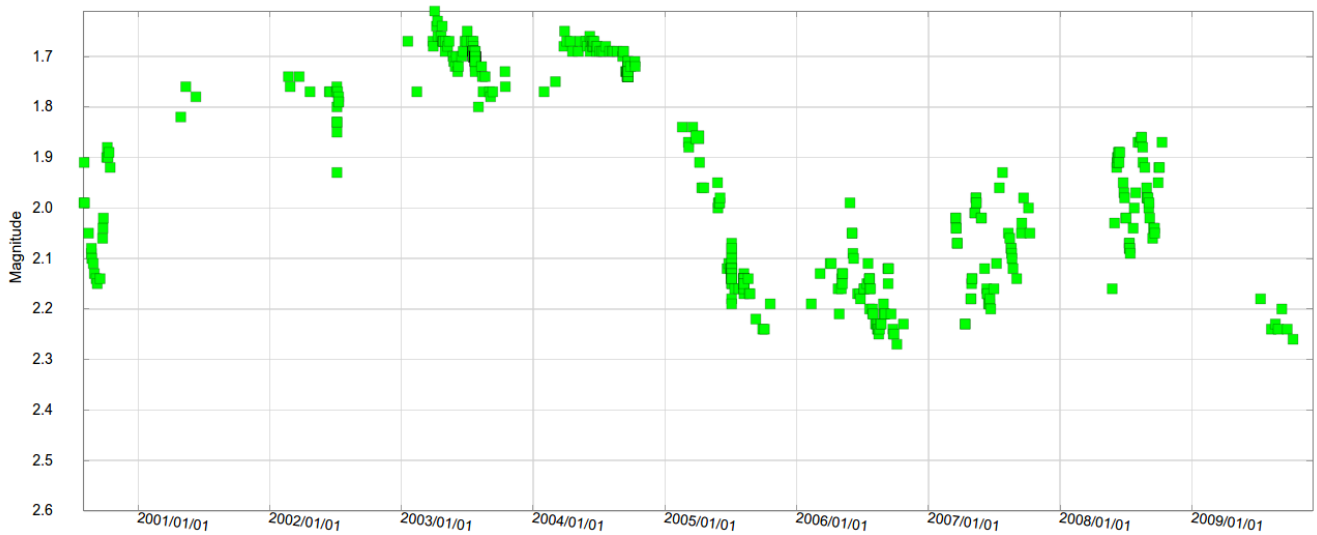
Kraus rejected all data not from P6M, who is highlighted below.



P6M data for rho Cas highlighted

Del Sco

V band data from 2000-2009 were used in a 2020 paper by Suffak[39]. The author states, *We selected only the data that had the"verified"flag attached to it,to ensure the photometry was of good quality.* Below are the validated PEP data.

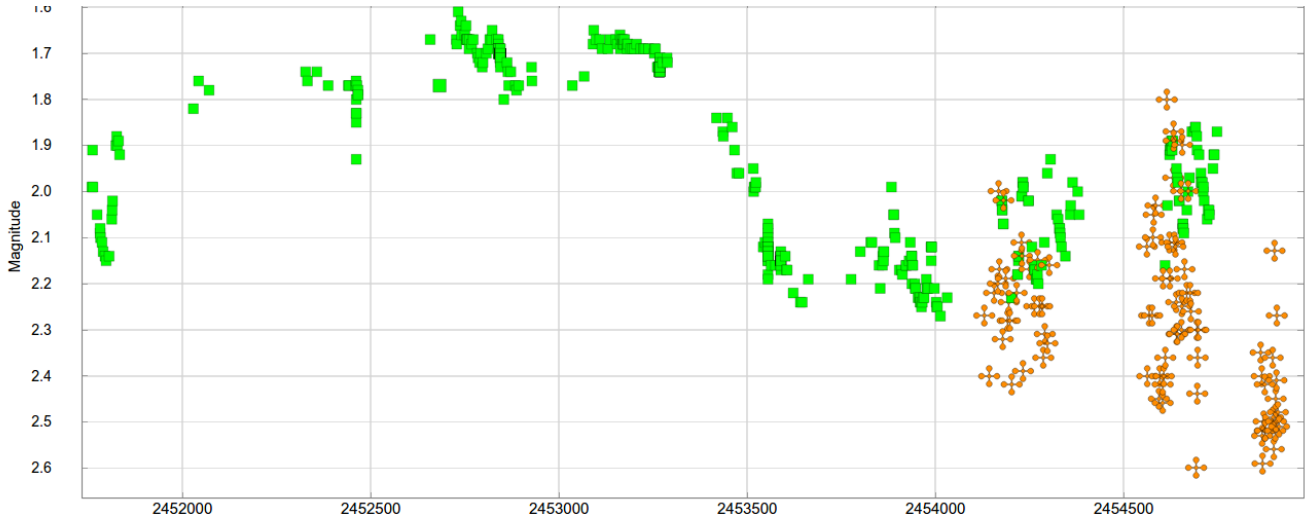


Validated PEP for del Sco

Curiously, almost none of these data have values for error, airmass, or comparison and check magnitudes (and identities). How could they have passed validation?

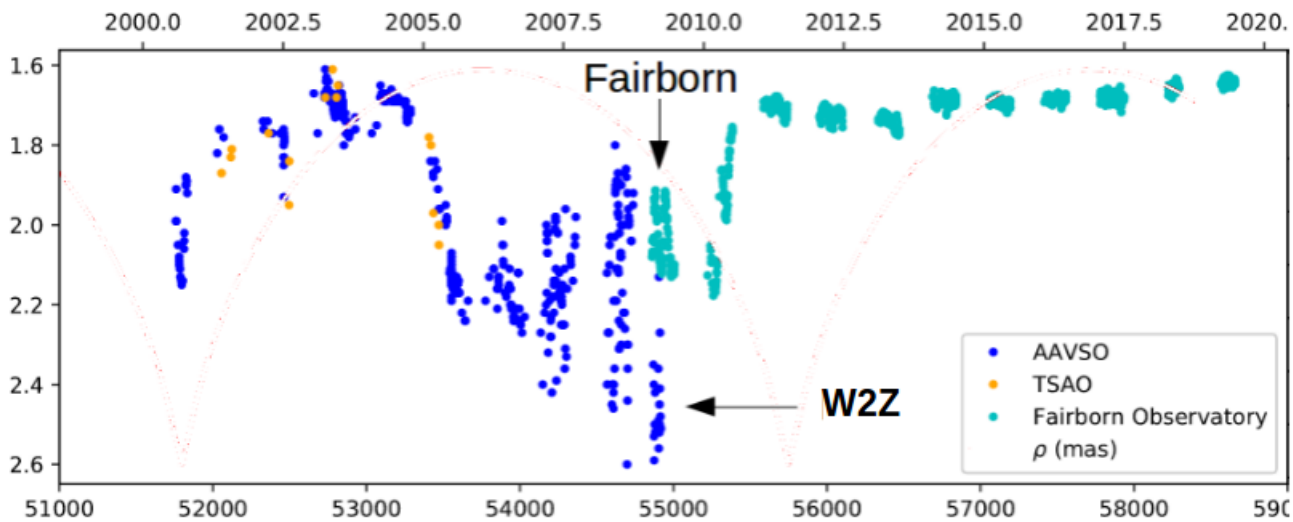
39 https://iopscience.iop.org/article/10.3847/1538-4357/ab68dc/pdf

Now let's add the primary CCD observer, W2Z:



W2Z highlighted

If anyone is discrepant, it's W2Z. But his data are marked validated as well, despite also having no errors, airmasses, or comparison info. The author's own diagram (below) shows that W2Z's deep dimming at far right, above, is incompatible with data taken at Fairborn Observatory:



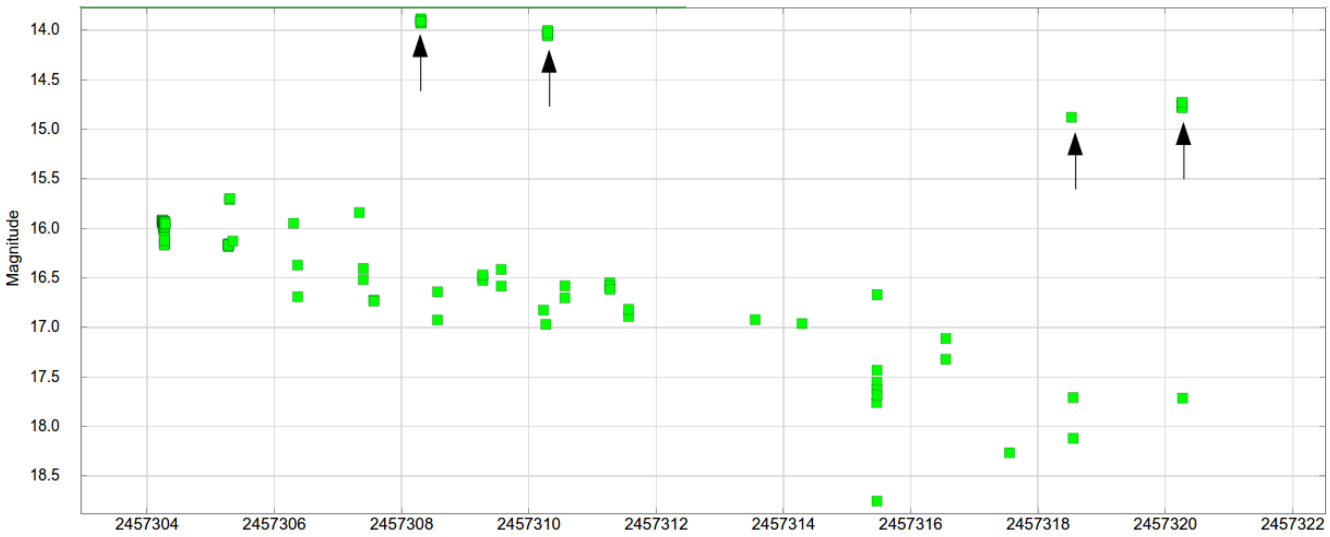
V band data. Blue dots=AAVSO, teal dots=Fairborn. Note disagreement just before (24)55000.

X Per

This star was the subject of a 2018 paper by V. Simon.[40] Regarding the AAVSO data, he says: *An inspection of the light curves showed that using only the AAVSO CCD measurements with the quoted standard deviation...smaller than 0.1 mag significantly diminished the noise and improved the lightcurves*. Some 38% of the observations failed to meet that standard. A case can be made that observers should gather as much data as they can and let the researchers decide what is useful. But a case can also be made that the X Per observers who reported high errors were wasting their time and should have been looking at other targets. [The median value of the "large" errors was 0.18.] Observer IC5 appeared to be using two different B-V values for X Per, but he is not consistent about reporting which one is in use for any given night.

Nova Aql 2015

Data for this event were used by in a 2018 paper by D.P.K. Banerjee.[41] He remarks: *To estimate t_2, four discrepant datapoints had to be excluded from the AAVSO light curve. These rejected points were isolated outliers and obviously erroneous, lying as much as∼2–2.5 mag away from their neighbouring data.*



Four bright points "obviously errorneous."

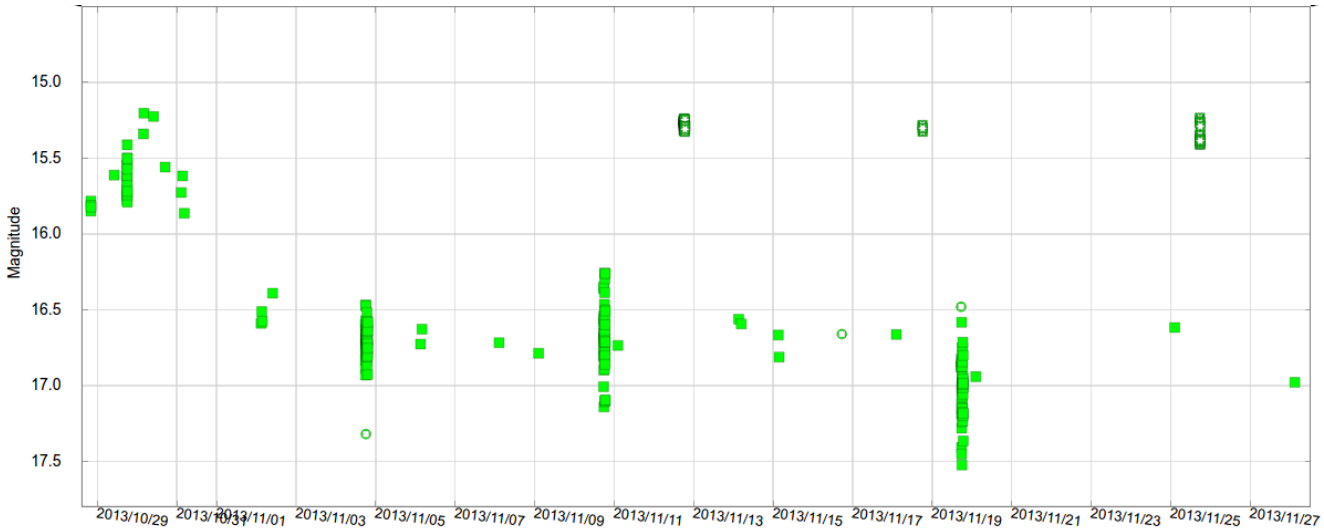
Three of the four "points" are actually groups of points, all from the same observer. S9T, responsible for all but one of the bright points, above, also had too-bright data for V519 Cas in this time frame. One could also question the dim point at 2557315 (by someone else), which is a full magnitude fainter than its predecessor of only 6 minutes prior.

40 https://www.aanda.org/articles/aa/pdf/2018/06/aa31308-17.pdf
41 https://arxiv.org/pdf/1709.06585.pdf

Nova Aql 2013

Munari, in his 2014 paper,[42] wrote:

For some dates, the AAVSO data are in the format of a series of rapid measurements (protracted for hours) from the same observer, that we have averaged into a single data point... The reason for that is the large scatter present in these AAVSO timeseries. The scatter does not seem related to the intrinsic variability of the nova but more likely to the low S/N of individual data points (short exposures with very small telescopes on a very faint nova low on the horizon) and to the absence of proper colour correction of the observations to transfer them from the local to the standard system... The very red colours of the nova (far redder than typical surrounding field stars) and the large changes in airmass and sky transparencies encountered during these long time series runs, suggest the apparent variability present in the AAVSO data to be an observational artefact.



Vertical V stripes are the timeseries by W0Y. He is also the three groups of too-bright CV data.

Nova Del 2013

I will close with one of the few cases where poor data got scrutinized and dealt with. From a forum post by Arne Henden:

> *Looking at the light curve, I'm pretty proud of the visual observers. Your observations are mostly fitting into a peak-peak distribution of about 0.5 mag, meaning the RMS uncertainty is in the 0.1-0.2 mag range. Not bad!*
>
> *I am NOT so pleased about the digital observers. Your observations are also mostly fitting into a peak-peak distribution of 0.5 mag. Your distribution should be at most 0.05 mag, or a factor of ten better... AAVSO observers are not transforming their data, are not observing with proper cadence and multiple image sets, are not watching for saturation or other defects in their images.*

42 https://arxiv.org/pdf/1403.3893.pdf

He proceeded to work with some people to diagnose their troubles. I excerpt a few of his comments here:

> *...R1F was nice enough to share these images with me on VPHOT. Looking at them, with the default settings of VPHOT's photometry tool, I get the results mentioned by Terry - a big difference between using the 80 and the 98* [comparison] *stars (0.1 mag)....So why the difference...? The answer in this case is that he is using the default settings of VPHOT, which specify an aperture radius of 4 pixels... that aperture is way too small for a 7pix fwhm star.*

> *...There are several observers using unfiltered cameras. I really recommend that you observe some other target. Novae* [spectra] *have all kinds of structure, like emission lines, that really mess up any kind of magnitude estimation with an unfiltered system. Your magnitudes are usually too bright, and can't be correlated with anyone else's.*

> *...R0W 2456542.55348 is about 0.06 mag brighter than I57's last point... The reason I am suspicious is that R0W reports an airmass of 4.046. While getting that first or last observation is important for some campaign targets... it really isn't needed for a nova. Instead, such high airmass observations are fraught with possible systematic errors.*

> *...The link that you gave for the Baader filters is interesting, as it gives the filter transmission curves for their UBVRI filters...it seems to indicate that the Baader filter has a longer red tail than does the Astrodon filter. The Baader filter appears to have 10% transmission at Halpha (656nm), falling to zero transmission around 720nm... The Astrodon filter has near zero transmission at Halpha...the nova has a huge Halpha emission line, and that may be contributing enough light to make your observations significantly brighter than other observers.*

> ...[C0P] *quotes an uncertainty from 0.005 mag to 0.05 mag per point. Yet, the observations have peak-peak amplitude of 5.12-4.64 = 0.48 magnitudes... So several comments: (1) the error analysis is wrong; (2) the images are likely saturated; (3) with this poor of a dataset, there is no reason to be reporting with this* [high] *cadence; (4) <u>such datasets obscure the really good ones...</u>*[43]

> And, finally:
>
> *...If you want to see what you should be getting with CCD systems, look at the data from SS5 on 2456521. He was using an Optec SSP-3 single-channel photometer...why can't we do this good? The data are precise, to within a millimag or so...if all CCD observations looked like the PEP observations, researchers would be ecstatic and would clamour for AAVSO data.*

43 Emphasis mine.

Summary

From the examples above (and the appendicies) I summarize some difficulties:

- Missing metadata (especially error, airmass and comp/check info)
- High airmasses (in general, and ensemble reductions at high airmasses in particular)
- Measurements undermined by large uncertainties
- Wrong comparison star
- No transformation (or bad transformation)
- Image saturation
- Not following campaign instructions
- Omitting second-order extinction in B band
- Scintillation in short exposures
- Inappropriate cadence (includes observations that should have been averaged together)
- Incorrect error estimates
- Extinction across DSLR field-of-view
- Comparisons with poor color match
- Unstable transparency
- Filters not conforming to standard passbands
- Poor placement of target in field-of-view
- Calibration errors
- Unexplained scatter from some observers
- Questionable data declared "validated"
- Undocumented calculations of uncertainties
- Untraceable ensemble stars
- Ambiguous or non-AAVSO comparison/check star identifiers
- Inappropriate aperture sizes
- DSLR TB and TR measurements of red stars
- Undisclosed non-standard passbands
- Incorrect observation times
- Mistakes in editing metadata by hand

And the over-arching problem: observers are not checking their own data for problems (in the light curve generator).

Online information about the AID

In some quarters it is held that professional astronomers *know* to contact AAVSO HQ for help sorting through our data. In the case of researchers involved in formal campaigns I'm sure this is true. But for astronomers simply coming to our website looking for photometry, I doubt it. I would like to point out that new website offers no guidance at all for evaluating our data for reliability. A legacy page of guidance (carried over from the old site) can be found if you know the URL, but there is no way to navigate to it on the new site. Assuming that we make that "data guide" webpage findable again, here is what a visitor would see:[44]

> The AAVSO has CCD data collected from amateur telescopes starting around 1995. The increase in quality of consumer-grade CCD cameras and the decrease in their price has led to an enormous increase in the amount of CCD photometry produced by AAVSO observers. The AAVSO currently receives approximately one million CCD observations per year. A large fraction of these observations are time-series observations of specific stars. The vast majority (> 99%) are obtained via differential photometry rather than all-sky photometry. While a significant fraction of the data are taken using standard photometric filters (e.g. Bessell, Johnson-Cousins), only a small amount of the total are fully calibrated, transformed magnitudes in the standard system of the filters used. Most are filtered magnitudes without zero-point corrections or nightly extinction corrections. For that reason, caution must be exercised when using untransformed data, and when combining the observations of multiple observers. For many practical applications (e.g. analysis of differential time-series photometry) you will find that AAVSO data are largely identical in quality to photometry obtained from professional research observatories, and the reduction techniques applied to standard differential photometry are easily applicable to AAVSO data.
>
> ## Data quality
>
> Data obtained by amateurs can be of very high quality with most observers capable of attaining photometric errors much less than 10 mmag on brighter stars. The limiting factor on absolute precision is typically calibration: transformation to a standard system and proper extinction correction.
>
> Amateur data are as subject to errors as professional observations. An an example, many of the analysis tools used by the amateur community do not clearly flag pathological data (e.g. saturated stars) when these tools are used to automatically reduce large image sets from a given run. As a result, some AAVSO CCD data show much larger scatter than would be expected; this commonly occurs at the bright end. Many photometry packages also do not calculate photometric errors, and it is common to find data in the AID where each data point has been assigned the same rms error. As with any other data set, AAVSO data should be critically examined prior to use in any analysis.
>
> ## Observation time
>
> The Julian Date (JD) is the time standard for all data in the AID. We have specified that the observers should be submitting data to the AAVSO using the **mid-point of the exposure time** for all CCD exposures. This specification was also given to all CCD and image processing software vendors whose software extracts photometry from CCD data and exports to the AAVSO Extended Format.

44 https://www.aavso.org/quickstart-guide-using-aavso-data. I omit the notes on visual data.

The data are always provided to the researcher with the Julian Date as the primary time stamp for the observation. When observers submit data in HJD, we store their HJD and also provide it to those who download the data, but we then populate the JD field by backing out the heliocentric correction after the fact. Depending upon the analysis you plan to do and the span of data you plan to use, we suggest using the JD and converting the observation times to HJD. Integration times for CCD observations are rarely shorter than one second, and so higher order corrections are rarely appropriate or necessary. Note that the HJD is irrelevant for observation times given to a precision of less than 0.01 days.

Filtered data

CCD photometry submitted to the AAVSO are a mixture of filtered and unfiltered photometry. In all cases we list filter information as provided by the observer. Filtered data will be noted as such, and our filter designations conform to standards (e.g. Johnson-Cousins, Sloan). When data are unfiltered, we encourage the observer to note whether their comparison star magnitudes are given in the V bandpass or the R. Such data will be marked as "CV" or "CR" (for "clear filter, V zero-point" or "clear filter, R zero-point"). More recently, observers have been submitting data using the RGB filters commonly sold with imaging cameras. Such filters do not conform to standards, but are designed to create true-color images. Such data is designated by the filter names "TR", "TG", and "TB" (tri-color R,G,B). Rarely we may have data for other filters, such as an orange photographic filter, older Johnson-perscription [sic] R and I, or Wing IR filters. If you have any questions about the filters with which data are taken, you should consult our list of available filters or contact us directly.

Calibration, exinction and transformation

Most observers do not perform a full transformation and extinction correction of their data even when using standard photometric filters. When observers use comparison stars of similar color and restrict their observations to low airmasses, the data can be remarkably consistent from observer to observer, with the sole limiting factor being a simple zero-point correction. However, **this is not a rule**, and observers *may* be using inappropriate comparison stars over a larger range of airmass than is warranted. Researchers should be aware that most data are not transformed or extinction corrected, and should treat them as such. For many purposes (e.g. time-series analysis) zero-point corrections are not required, and the data may be used with a simple transformation to a common zero point.

The status of calibrations is given in the "transformed" field; if the data are transformed, they will be indicated as such. Fully transformed data is rare in the AID, making up only a few percent of the total. When using filtered data, you should be aware that even "V-filtered" data are not necessarily transformed to the standard Johnson-Cousins system, and that there may be other effects such as differential extinction present. If you have questions about this, please contact the AAVSO for assistance.

First, I would like to note that the guide says nothing about interpreting DSLR or PEP photometry. Second, the reader is presented with numerous cautions, but no decision procedure for choosing what data to believe. Finally, it scarcely covers all the problematic "symptoms" to be found in the AID.

Assuming that we bring back the above data guide, I presume we will also bring back the web page with an "introduction" to the AID, which is also not directly available on the new website.[45]

> **The AAVSO International Database (AID)** has tens of millions variable star observations going back over one hundred years. It is the largest and most comprehensive digital variable star database of its kind in the world. Over 1,000,000 new variable star brightness measurements are added to the database every year by hundreds of observers all over the world.
>
> **Quality**
>
> AAVSO prides itself on providing the highest quality data possible to researchers. AAVSO implements data entry error checks for each observation at every stage in the process, and every month, staff comb through all the observations, both personally and through the use of automated programs, to look for misidentifications, typos, and any other errors. All revisions to the database are tracked, and no observation is ever discarded without thorough checking.
>
> Quality control begins before the observation is even made:
>
> - Extensive training materials are offered new AAVSO observers, such as online CHOICE courses and forums
> - AAVSO's active mentoring program pairs new and experienced observers
>
> AAVSO's online data entry tool, WebObs, runs error checking routines which automatically identify the most common data entry errors.
>
> For more in-depth checking, the observers themselves review their own submitted data (by using the following tools AAVSO makes available) and bring any questionable observations to the attention of AAVSO staff:
>
> - Light Curve Generator, version 2 (LCGv2)— a web-based tool that creates a light curve in real time using data from AID. Although primarily used for plotting light curves, users can report any discrepant observations. Unlike Zapper (a data-checking tool used by volunteers), LCGv2 can plot individual bands.
>
> - WebObs Search—a web-based data search tool that allows users to get a list of data based on search parameters, including an observers' code name (obscode), star name, observation start and end dates, and/or observation type. Observers can find and edit or delete their own observations, but they are not allowed to alter the observations of others.
>
> In addition, devoted AAVSO volunteers and staff check the accuracy of data submissions using the Java program Zapper to identify discrepant data points and send a report of any discrepant points to AAVSO staff for reviewing.

It is safe to say that this note presents a far rosier picture of our quality control than is actually the case. Most of the checks described are to catch data entry errors, not bad photometry. And as for actually flagging discrepant data, Sara Beck remarked in a forum: "I don't think anyone is doing it regularly."[46] That was in 2020, and I doubt that the situation has improved.

45 https://aavso.org/aavso-international-database-aid
46 https://www.aavso.org/how-many-starts-are-zapped

Regarding Diagnostic Tools

To get a feel for the difficulty of screening AAVSO data, pick a two-day period in 2021 and pretend that *you* have the responsibility for checking quality. Seriously: try it, then you'll see what we're up against.

Evaluation of the example data in this note was accomplished with the Light Curve Generator, WebObs Search, the data download portal, and VStar.[47] On the whole, they are inadequate tools for data evaluation.[48] One of the problems is a lack of consistent filtering options. WebObs can filter on observer and observation type,[49] but not on passband. LCG can filter on passband and observer, but not observation type. The data download tool allows no filtering at all.

The flood of timeseries has had a negative impact on the utility of the WebObs search function. A query covering only a day or two may turn up hundeds or thousands of series records from which other photometry of primary interest cannot be separated out. Navigating the search result pages then becomes a major headache. It would be helpful if WebObs had filtering to *exclude* groups of observers or targets.

A major drawback of the current AAVSO tool suite is that there is no way to visualize the light curves of check stars. I do this by downloading the observation records, then massaging the file with Unix tools so that the check magnitudes become new data records in some unused passband. Then I can see them in VStar (curves for check-minus-comparison would be useful, too).

As I understand it, an instrumental magnitude is -2.5·log(net_flux/gain/integration). But almost all the instrumental magnitudes one finds in the AID are positive numbers. Apparently, software packages are adding large positive constants to the instrumental magnitudes.[50] Instrumental magnitude should be better defined and documented.

The LCGv2 is still buggy, and it grinds to a near-halt when there are more than several thousand data points.

There is no way to look up the magnitude sequence of a comparison star by its AAVSO identifier. I would also like to point out two problems in the Variable Star Plotter:

> A) Some of the comparisons it serves up are known variables in VSX. When I set up for new targets in the PEP group I run into this all the time. It's a problem because the AAVSO identifiers for comparisons are not cross-referenced against other catalogs. To check a potential comp for variability, I must first learn its identity. The only way is to copy and paste the RA & Dec from VSP into SIMBAD for a coordinate search. Then I can look it up the ID in VSX (and Hipparcos).
>
> B) If you take the chart identifier from an observation record and plug it into VSP, it will only bring up the V and B-V data for comparison stars. That is to say, the identifier does not encode which passbands were actually used in the original chart.

47 Headquarters has an additional tool called Zap, but I have never seen it.
48 Zapper does not appear to offer much additional functionality. Based on the documentation, its users are only expected to detect major discrepancies.
49 DSLR vs CCD vs PEP.
50 https://www.aavso.org/aavso-extended-format-check-and-comp-star-magnitudes

Coda

The all-sky survey systems are not on the way–they're already here. EvryScope and projects like it will provide professionally gathered, professionally reduced photometry on a massive scale. No, EvryScope does not yet have a public access portal, but that is surely to come. Astronomers will have alternatives to AAVSO, and when we serve up erratic data products we are inviting researchers to turn elsewhere.

There are various steps that can be taken to address the problems presented here. Our observers *can* learn and improve if we ask them to, but right now we're not asking.

Appendix A: DSLR Notes (for Council, 2017)

AAVSO Archive Notes I

DSLR Data

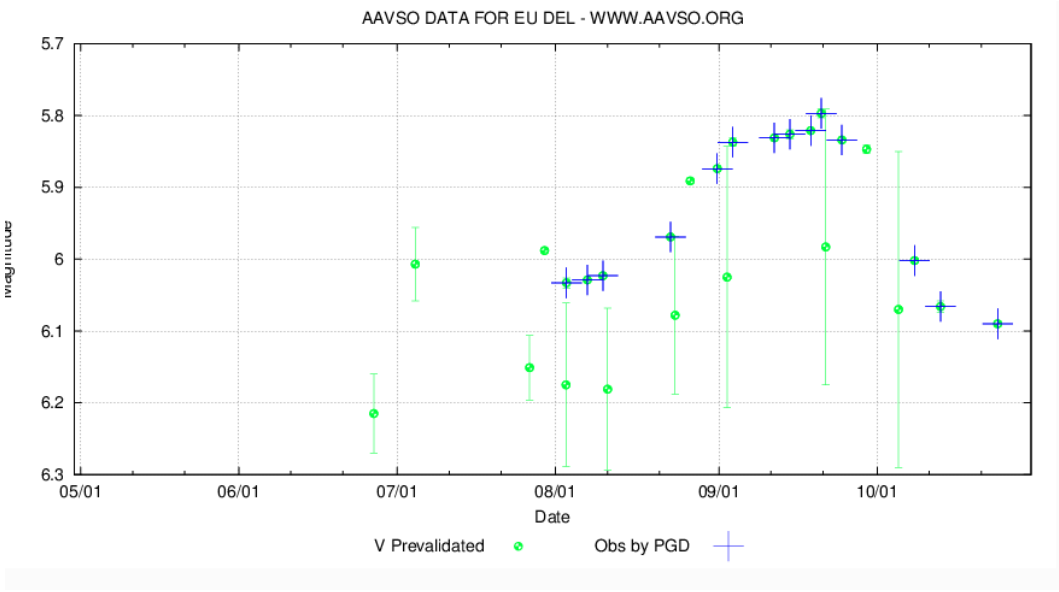
5 February 2016 (updated 13 Oct 2021)

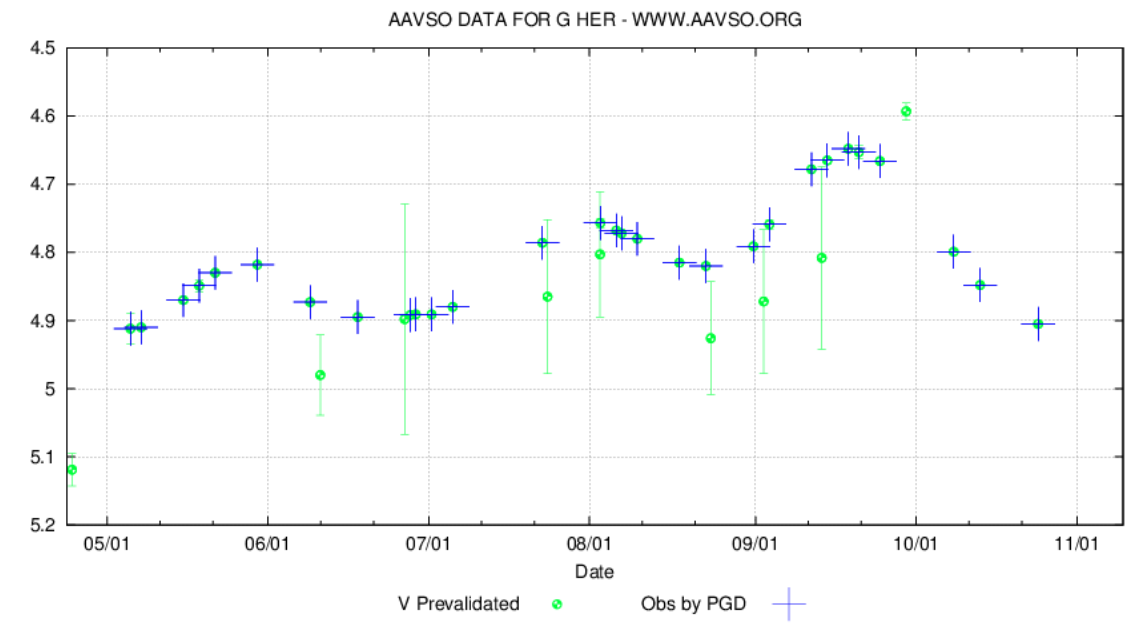
Tom Calderwood

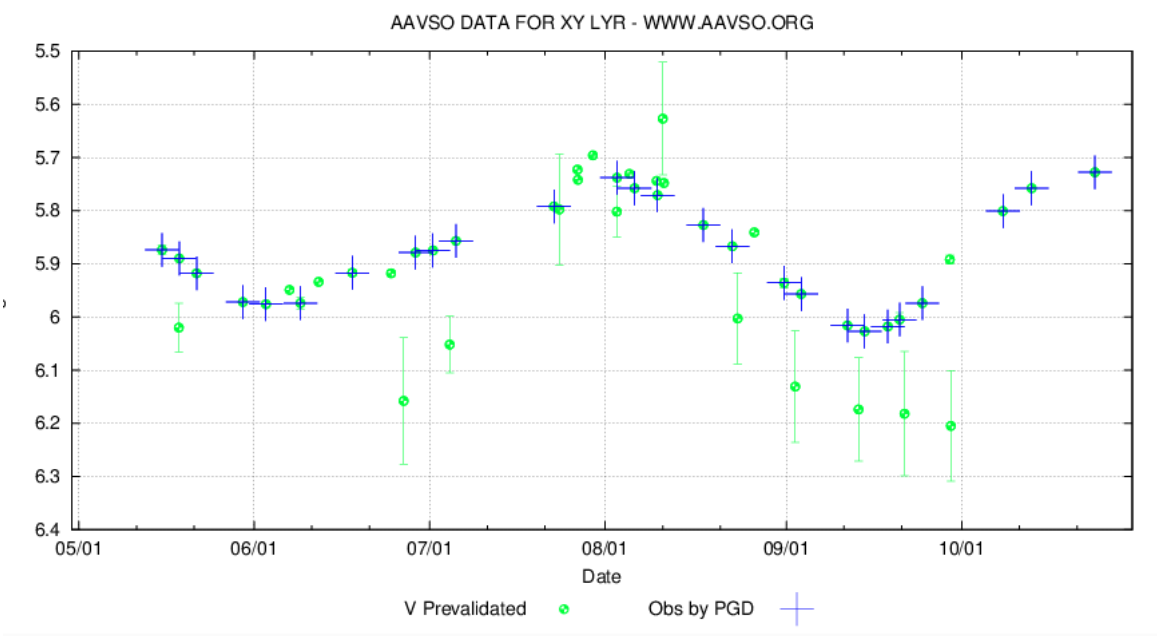
In the course of preparing our fall meeting presentation on observer consistency, Jim Kay and I had occasion to look at recent DSLR data in the AID. A number of problems were found, and this note is a summary of the findings. I am not trying to "pick" on DSLR—there are PEP observers committing some similar sins—but the sheer volume of DSLR data coming into the archive means that problematic observations are being submitted in large quantities.

1. Observers with systematic errors.

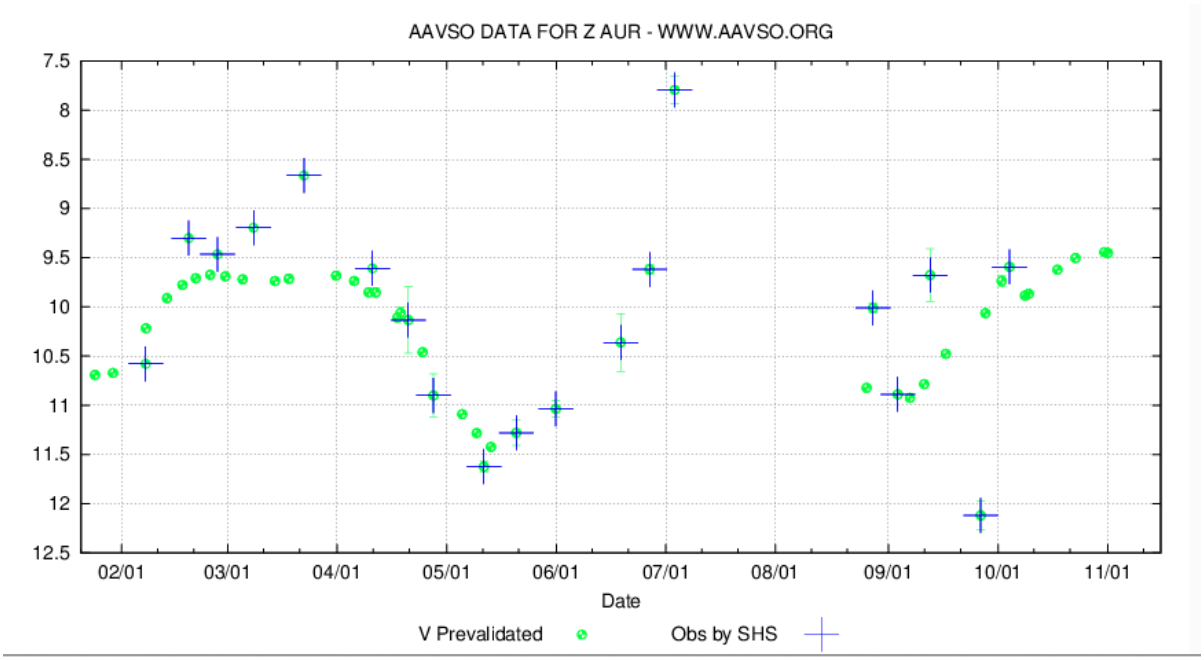
Below are light curves with data from SS5, experienced PEP observer (blue crosses), and DSLR observer K02.



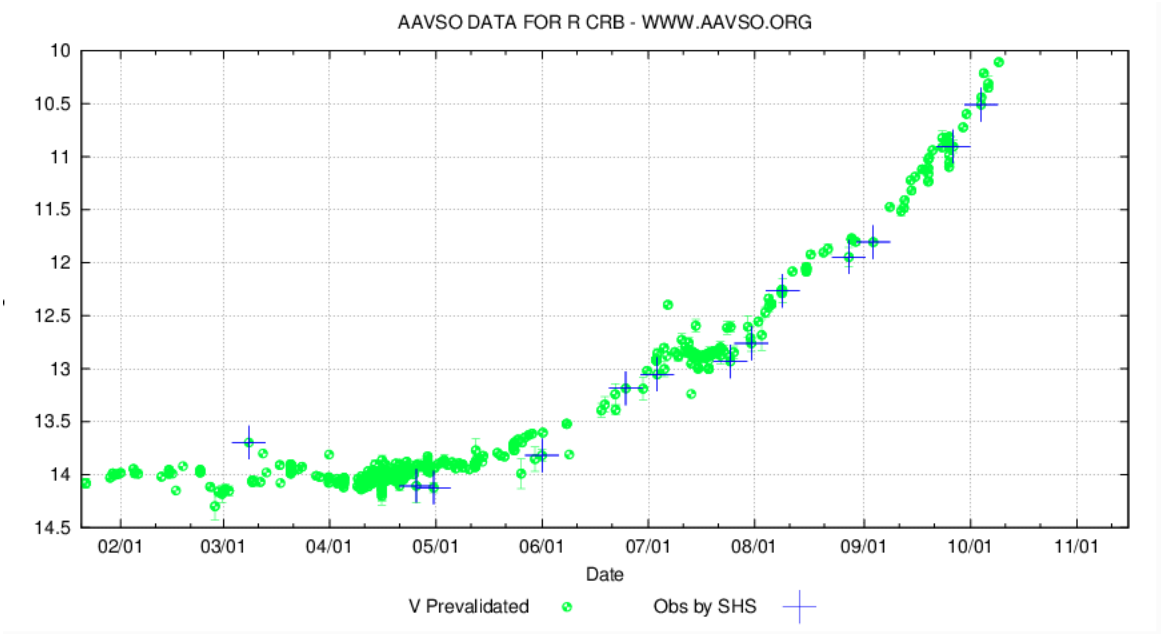

AAVSO DATA FOR G HER - WWW.AAVSO.ORG
4.5
4.6
4.7
4.8
4.9
5
5.1
5.2
05/01
06/01
07/01
08/01
09/01
10/01
11/01
Date
V Prevalidated
Obs by PGD


AAVSO DATA FOR XY LYR - WWW.AAVSO.ORG
5.5
5.6
5.7
5.8
5.9
6
6.1
6.2
6.3
6.4
05/01
06/01
07/01
08/01
09/01
10/01
Date
V Prevalidated
Obs by PGD

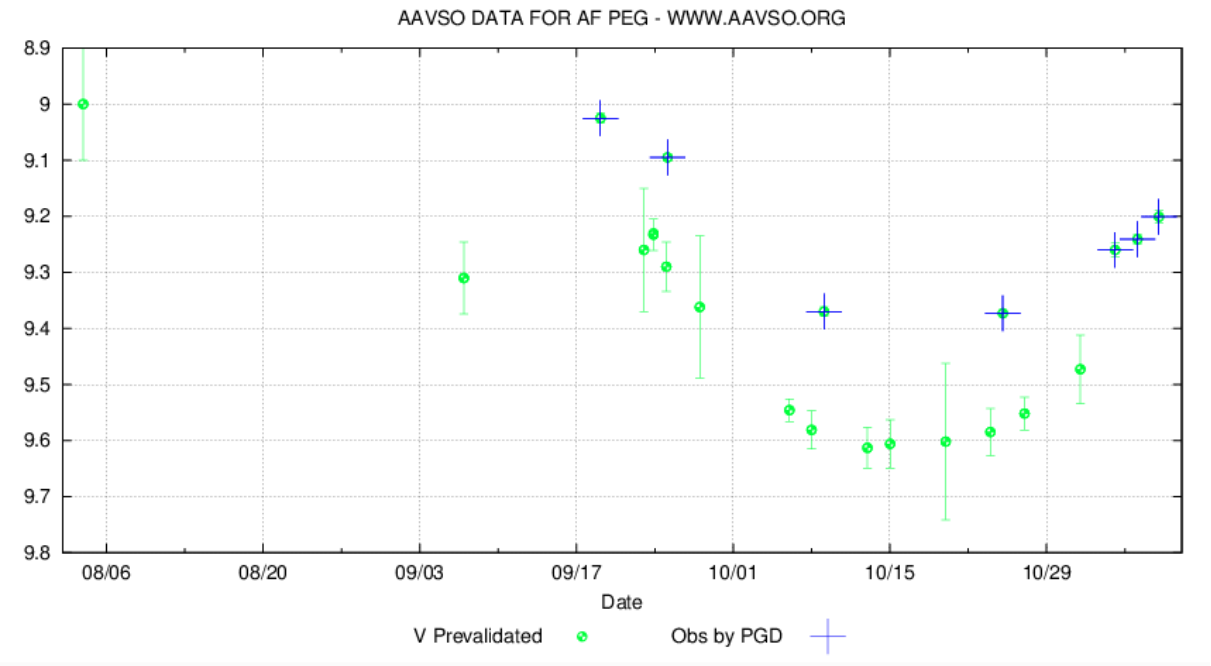
K02 shows a definite habit of being too faint, but not always. Below, he is the blue crosses:



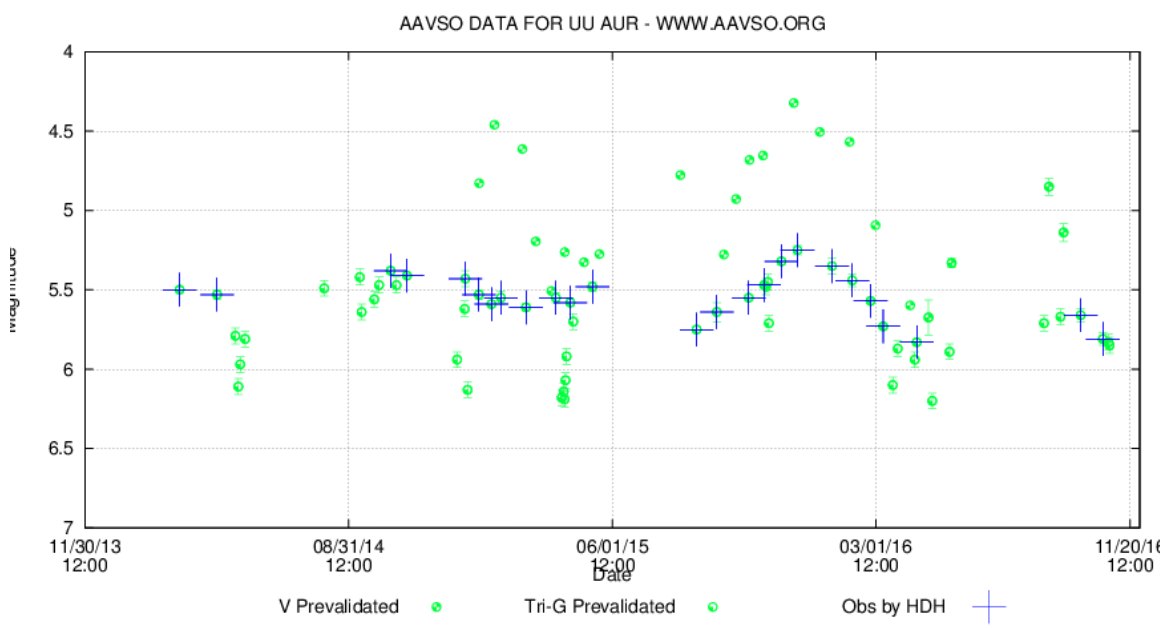
And sometimes he does reasonably well (blue crosses):



Here is a nice curve from D3C, apparently using the wrong comp star or comp star magnitude (SS5 crosses):[51]

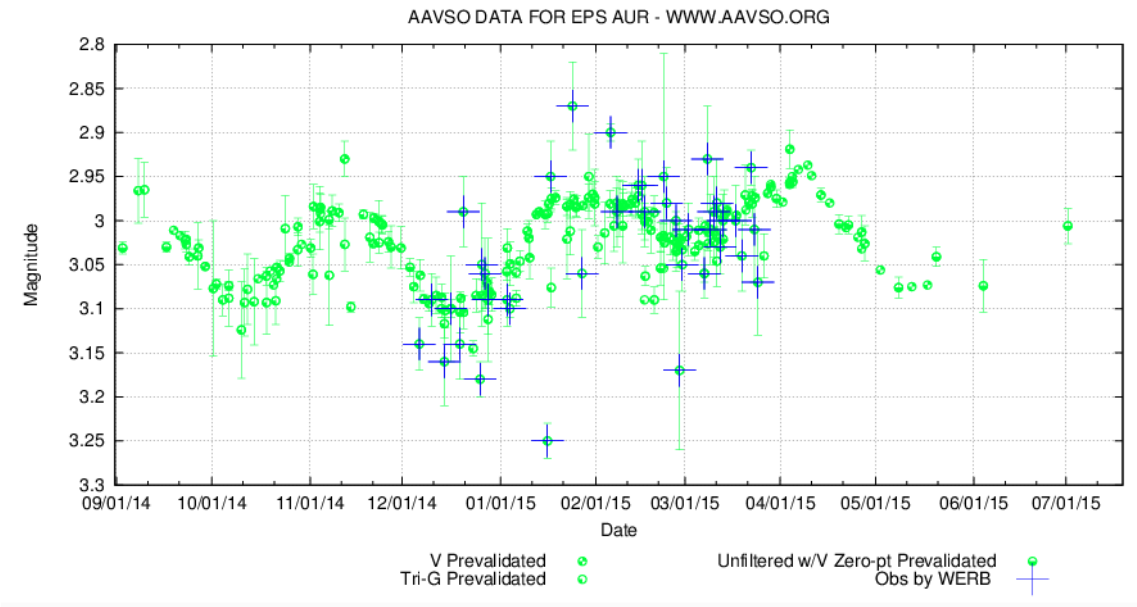


Here is observer K3V on UU Aur. Blue crosses are I6P, who appears to be reliable; K3V DATA are the rather dim points below him (I trimmed out one howler at V=~14.3). The overly-bright data points are K02, again.

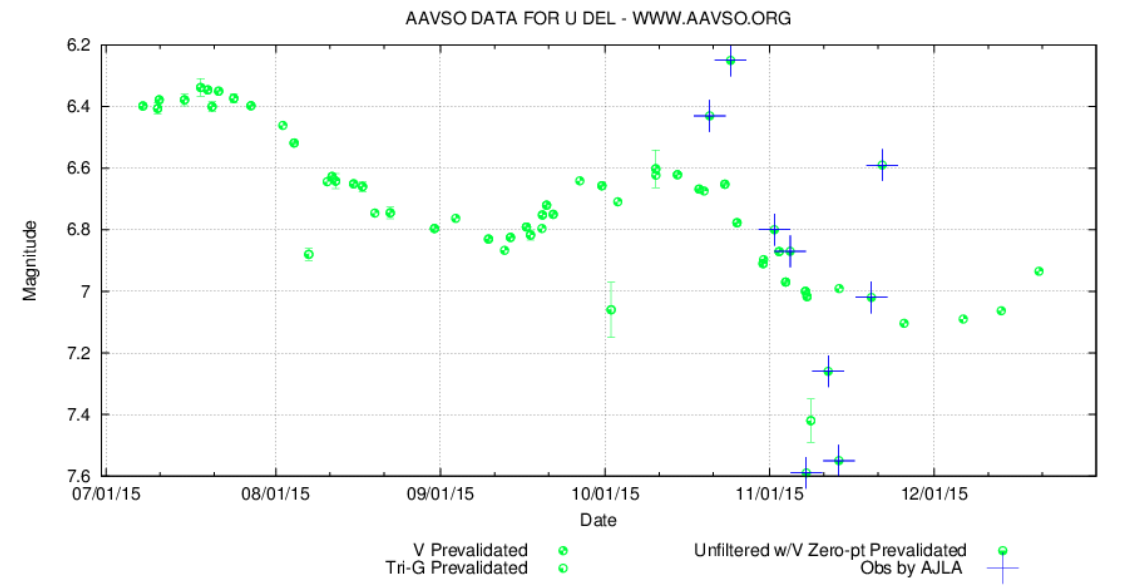


51 I suppose it is conceivable that SS5 is using the wrong star or magnitude, but *somebody* is off.

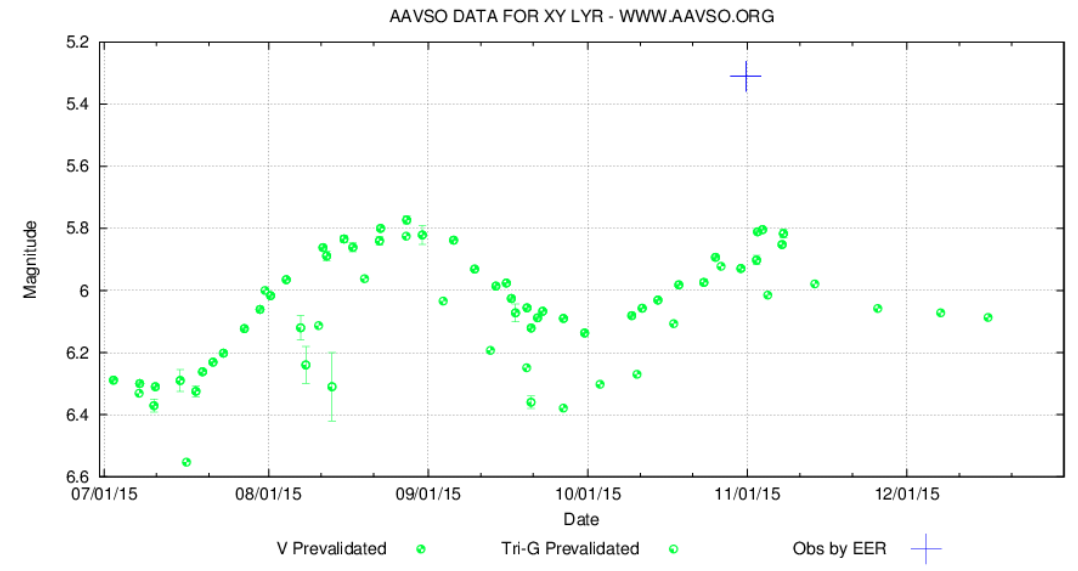
On eps Aur, A3X is questionable:



N33 on U Del is very questionable:



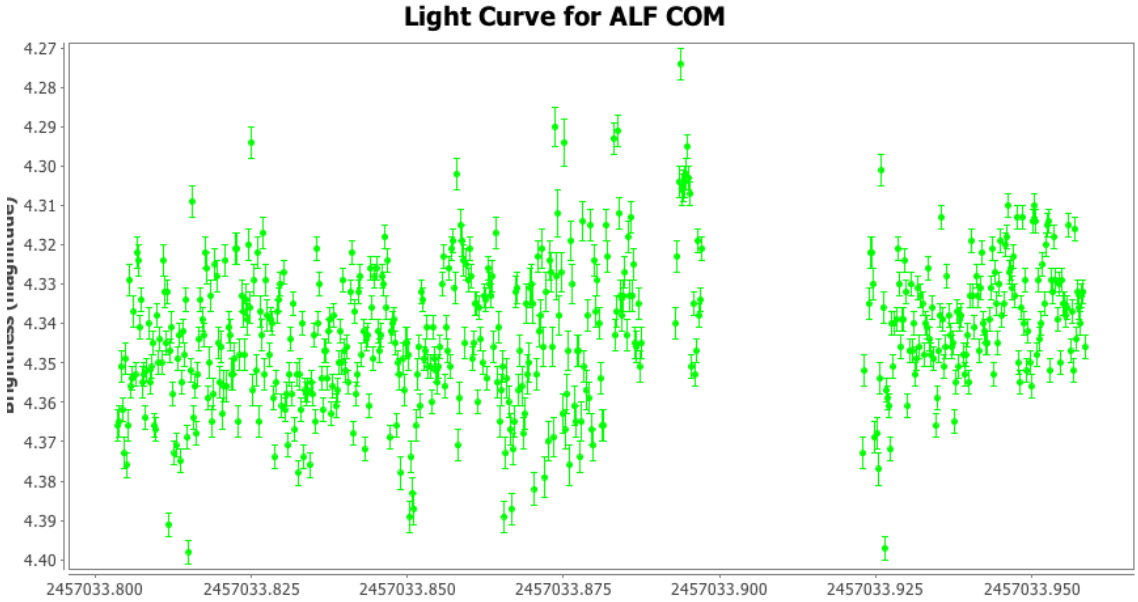
Below, a bright outlier from S4T on XY Lyr: V4K (large error bars), G8A (small error bars), and K02 (no error bars) are responsible for the dim points.



In these examples, the DSLR observers are mostly operating unfiltered with V zeropoint, or as TG, so one would not expect exact agreement with transformed V PEP data. However, the range of deviation is so great that it is hard to believe that serious problems are not involved.

2. Observers reporting unrealistic errors.

Below is a time series for alf Com, an apparent dry run for the abortive eclipse campaign of 2014-5:

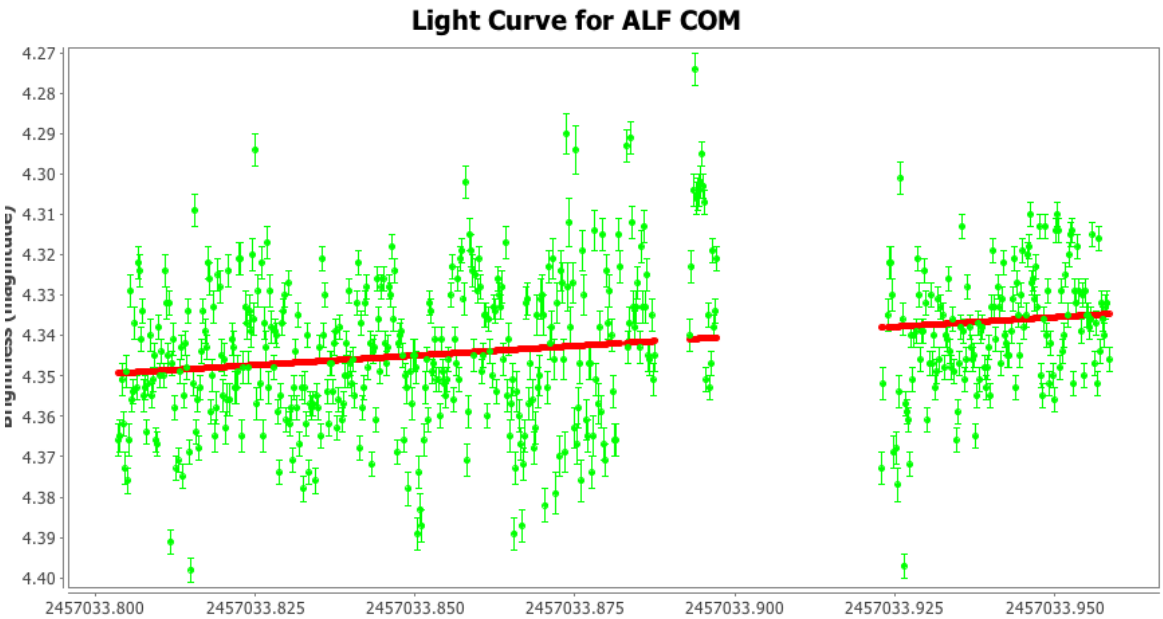


The mean of these magnitudes is pretty close to the expected value for alf Com. However, the median error reported is 3 mmag, while the RMS for a constant-line fit of all the points is *18 mmag*.

Some observers report no errors at all. SN8 has submitted 20,000+ observations the last two years with no uncertainties. Errors of 0 are being submitted (DN7, mu Cep, 12 July 2012). Note that the WebObs observation editor will reject error values of 0. If the observer had to modify such an observation record, the editor would force him/her to change the 0 error to a positive value.

3. Extinction problems

Returning to the alf Com light curve, it is seen that the data have a brightening trend:



During the series, the star is rising towards the meridian. Differential extinction between the variable and comparison decreases, so the variable, which is east of the comparison, appears to get brighter. The field-of-view for a DSLR is large enough to require correction for first-order extinction.

4. Chart problems

Various practices render it difficult to determine the comparison star or its magnitude. Some observers are submitting BAAVSS chart identifiers (M0R Sep 2016). Some are listing comp stars that are not on the specified AAVSO chart (P6M, R Lyr, JD=2457611). Sometimes no comp or check is even specified (MI8, RZ Cas, 2457537). There are numerous examples of what I presume are ensemble comparisons where the comparison is listed as blank or "NA." N33 gives comp/check magnitudes instead of identifiers for U Del on 1 Nov 2015.

5. Incorrect classification of observations

DSLR observer K3V has data classified as CCD during 2014-2016. I suppose it is possible that K3V is using a non-DSLR color camera to take TG data, but from the observation record it is impossible to tell. P6M DSLR data is also classified as CCD (2016).

6. Fainter-than data

L0P is reporting fainter-than observations with uncertainties. How is this possible? Fainter-than means you can't detect the star.

```
2456556.41774,<12.352,0.248,,V,L0P,,86,107,12584AWX,,0,,Z,-10.057,-7.948,,RU AUR
2456558.36061,<12.666,0.222,,V,L0P,,86,107,12584AWX,,0,2.759,Z,-10.688,-8.498,,RU AUR
```

7. Missing airmass

L0P on RU Aur, again. Field before "Z" is empty.

```
2456528.49407,14.647,0.205,,V,L0P,,ENSEMBLE,105,12584AWX,,0,,Z,,10.540,,RU AUR
```

8. Inappropriate targets for unfiltered observations

Unfiltered data is useful for monitoring CVs, for establishing periods, in cases where comparisons with matching B-V are available, or when operating near the instrumentation sensitivity limit. But observers are shooting large fields and reporting data for multiple stars at once. In principle, the ensembles used could be made up of stars with matching B-V for each variable, but far more likely that the observer is using a single ensemble for all of them, which is not appropriate. In any case, the observer is using a single check star for all variables, which cannot possibly match the different variable colors. Eg: G8A on 1 Apr 2016. Y CVn, TU CVn, NSV 19560, BZ CVn, CE CVn, CE CVn, BY CVn, BQ CVn, CD CVn, TW CVn, and NSV 5976, all on chart 13353RG. Observer M0R seems to be doing this on a more limited scale in Sep 2015 with V Aql, R Sct.

9. Large errors

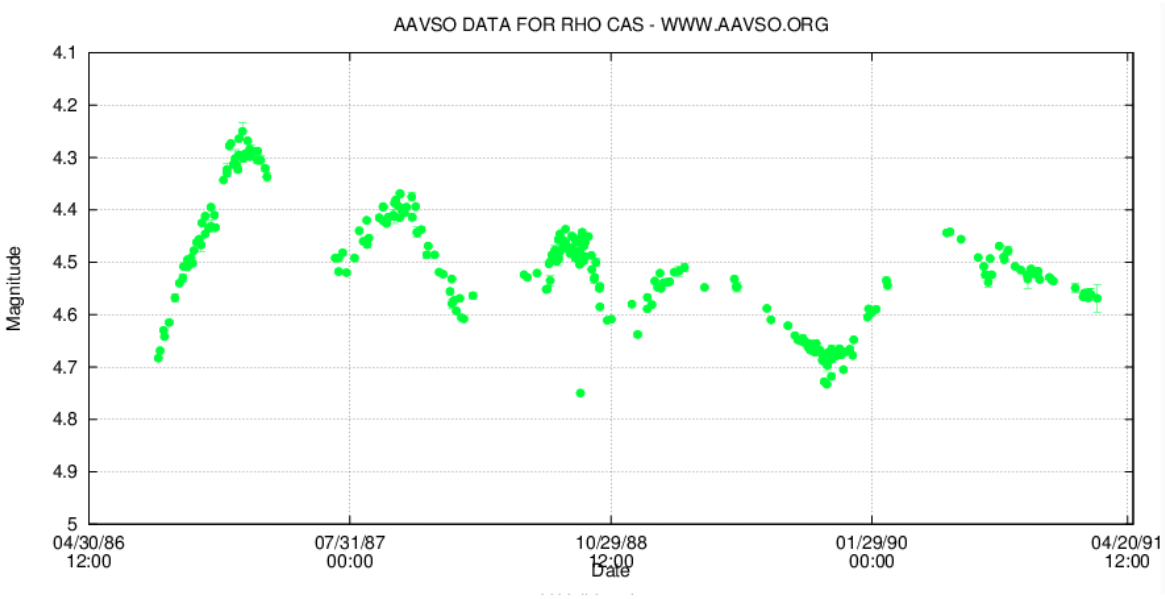
There are observations reported with uncertainties north of 0.2. These are no better than visual data—do we really want them in the archive? Perhaps in addition to the "discrepant" category, we need a "low quality" category. It might also apply to data taken at excessive airmass.

10. Missing metadata

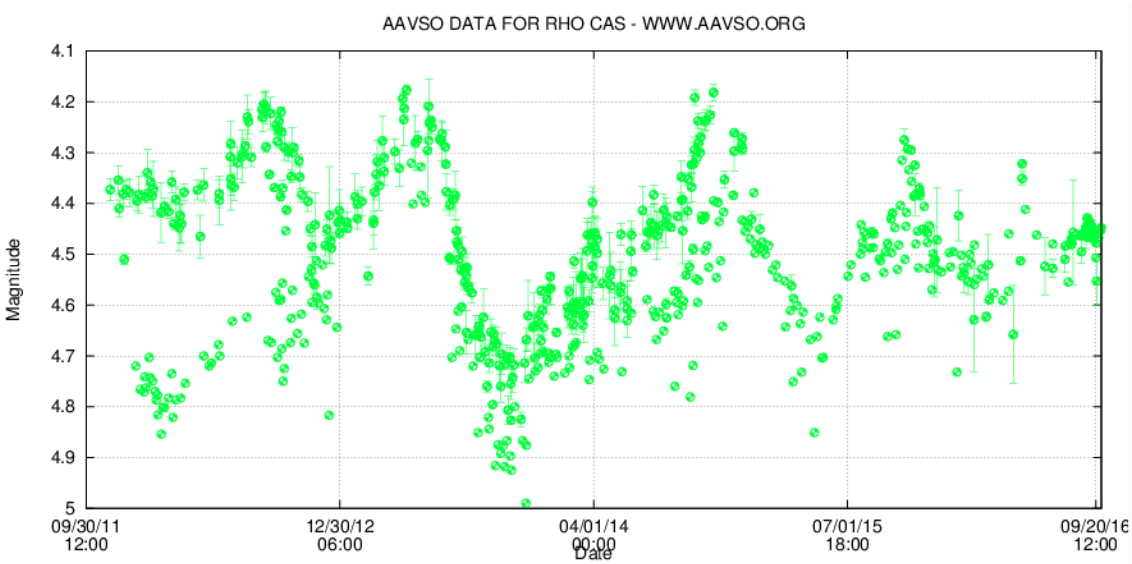
Observers often do not identify the equipment they used. There is no requirement that they do so, so I can't say this is an omission, but it can be placed in the COMMENTS and would be a big help. It would also be nice to know the software used for reduction. [In PEP, we are looking at standardized information for the comment field to convey this and other information.]

11. Conclusion

It should be noted that assembling this sample of anomalies was a very laborious process—we don't have tools to efficiently evaluate the archive contents. Also, CCD data were not considered, and we can reasonably assume that similar problems exist in that domain. Finally, I *will* pick on DSLR. Here is a five year light curve of rho Cas from the heyday of PEP observing in the 1980s. 268 data points by fourteen observers. Top five observer totals were 45, 43, 41, 37, and 36. Median uncertainty is 3 mmag.



Fairly good-looking curve. Now, here are the last five years of data from DSLR observers. 532 data points from eleven observers, top five totals: 243, 214, 31, 24, 5. Same vertical scale. P6M, the most prolific and reliable observer, had a median uncertainty of *26 mmag*. M0R, the other major contributor, did not even supply uncertainties.



It is not unreasonable to conclude that data quality declined as DSLR supplanted PEP.

Appendix B: CCD Notes (for Council, 2017)

AAVSO Archive Notes II

CCD Data

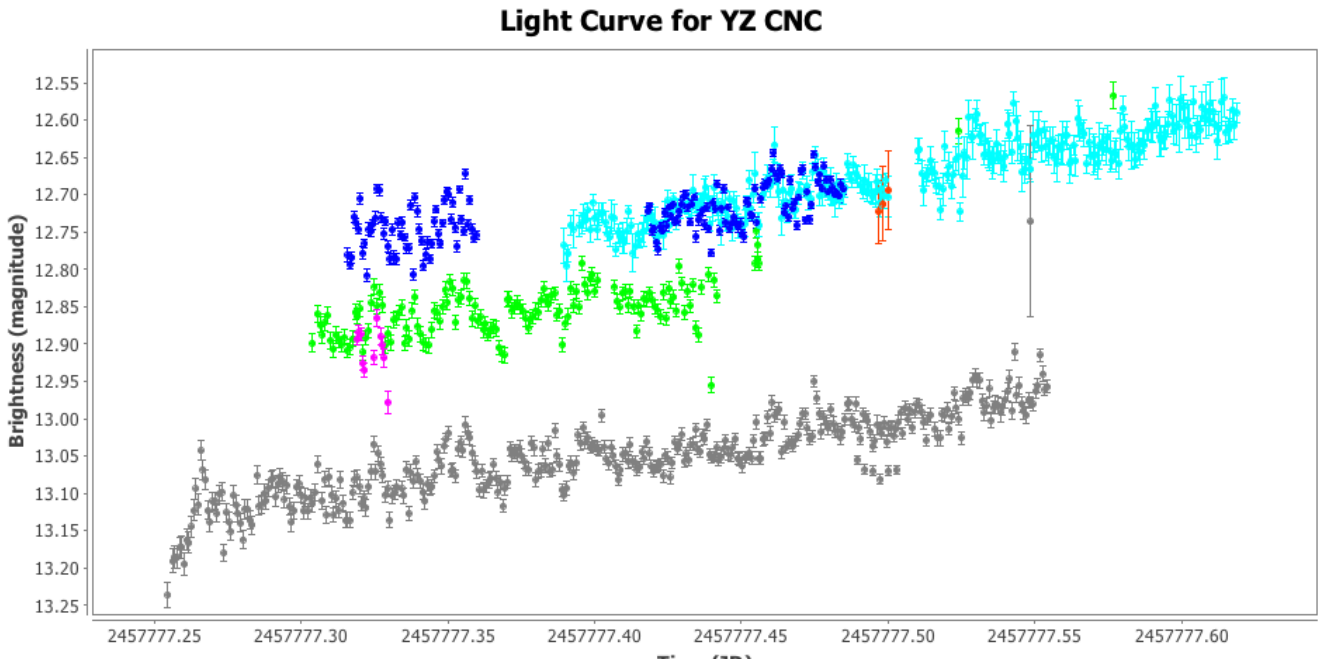
5 February 2017

Updated 29 October 2021

The first Archive Note identified several classes of problems noticed in DSLR data. I will not attempt a point-by-point duplication from the CCD records, but focus on some illuminating examples from campaign stars.

1. YZ Cnc

In the graphic, below, different colors represent V band data of different observers of YZ Cnc on RJD 57777: J9E, V5L, Q1W, and YY9. The latter observer is working in CV with a single comparison, while the others are untransformed ensemble.

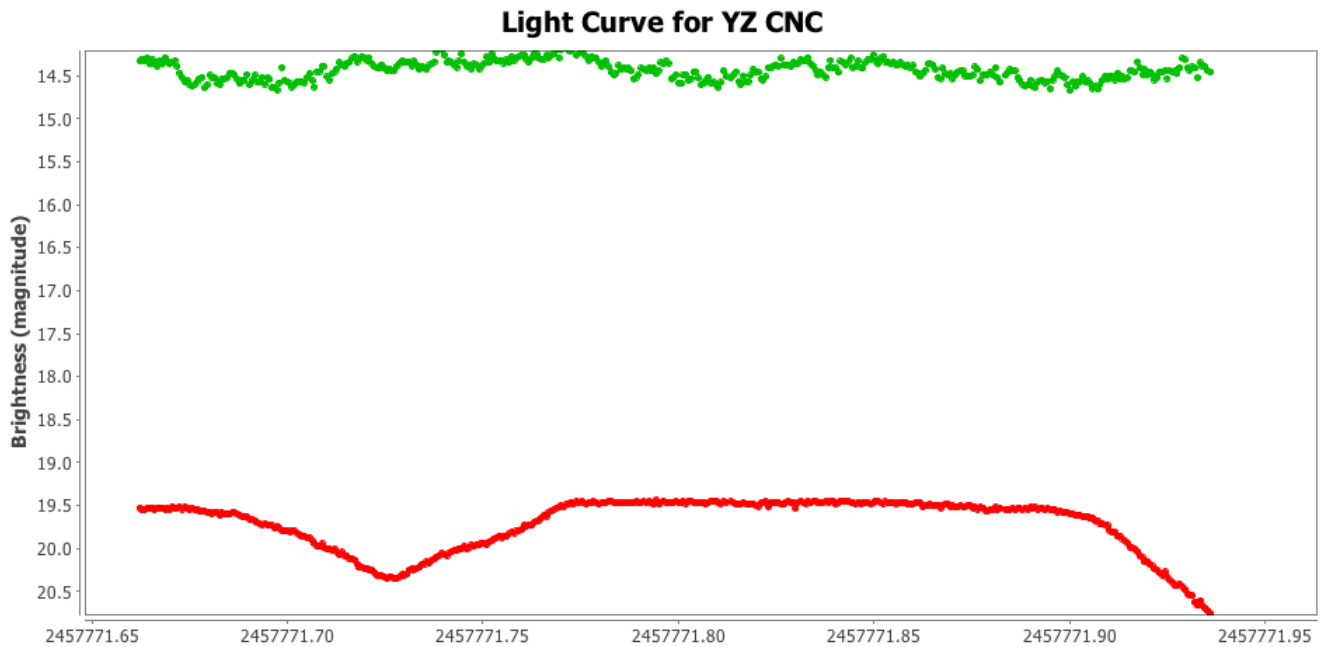


J9E V5L Q1W YY9

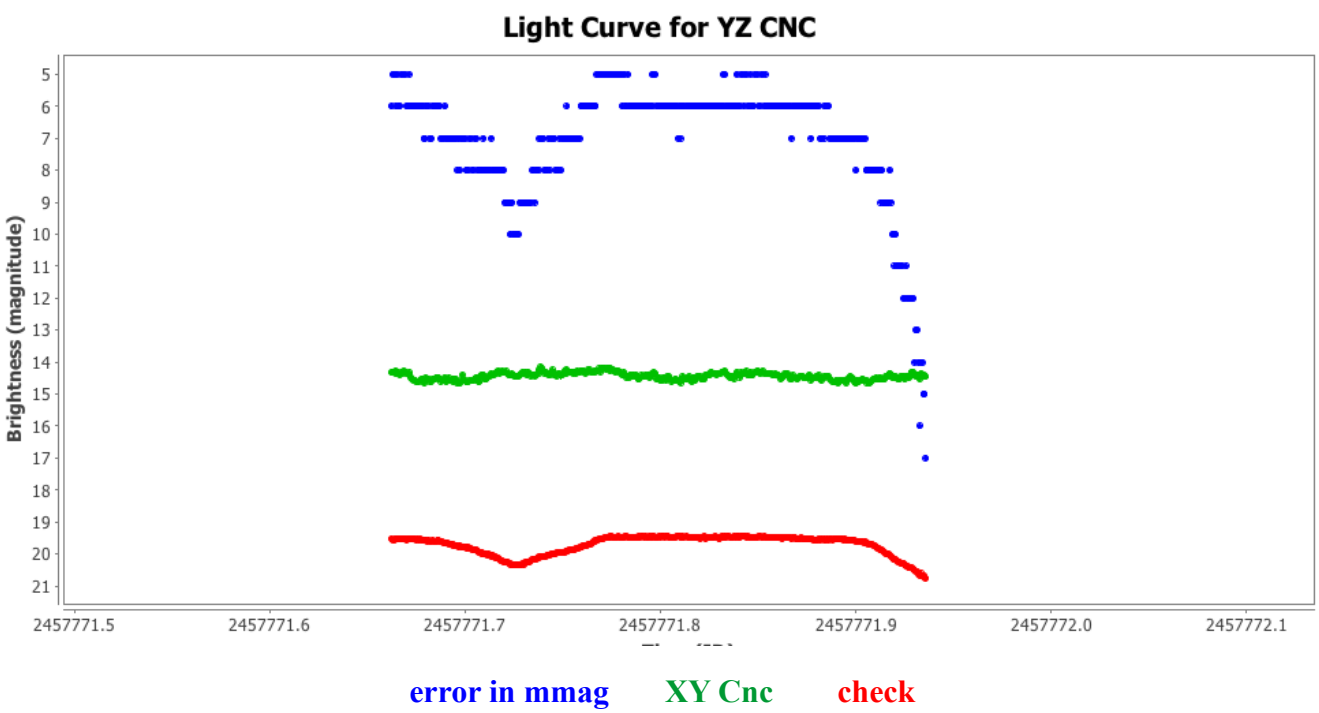
J9E and V5L are in fairly good agreement, but Q1W is about 0.12 mag fainter. Given that all three are using ensemble reductions, this seems large. For YY9, the mismatch is much worse, about 0.3 fainter. YY9's difficulty with YZ Cnc is probably partly due to inappropriate choice of a comparison for CV mode reduction. The comp used has B-V = 0.947, while the B-V of the target appears to range from about -0.4 to 0.1.[52]

52 In admittedly spotty B data in the weeks prior to the night in question. But a star with this amount of color change seems ill-suited to CV observations.

On RJD 57771, observer Ml2 experienced a wide variation in check star magnitude,[53] below.



Error bars are omitted in the above diagram, but the error values are plotted in blue, below (read the blue points as millimag errors instead of magnitudes).



53 Still in V band.

Errors increase significantly at the dip, and get quite bad, relatively speaking, at the end. Thin clouds may be the cause, which the observer should have noted. This may be an example of equipment left to run automatically while the operator attended to other things (like sleeping), and, if so, illustrates a hazard of that habit.[54] Of importance here: AAVSO data tools presently have no way to display check star magnitudes, so these diagnostic diagrams are not easily created.

On RJD 57751, observer R5R give duplicate times for the first two data points in his series:[55]

```
2457751.43540,11.319,0.005,,V,R5R,,NA,000-BBP-174,X17069MB,,0,3.655,Z,,10.158
2457751.43540,11.328,0.005,,V,R5R,,NA,000-BBP-174,X17069MB,,0,3.655,Z,,10.158
```

The airmass is suspiciously high at 3.655, and the time series concludes at airmass ~5.8.[56] R5R is in Spain. Assuming a location of Madrid, which is centrally located in the country, I estimate that his starting airmass should have been about 1.1. On RJD 57777, he takes another time series at approximately the same UT as on 57751, and gives airmass starting at 1.0, which seems correct. R5R keeps using the same reference stars on different nights, but specifies different charts, and gives a reference magnitude for the check star instead of the instrumental magnitude.

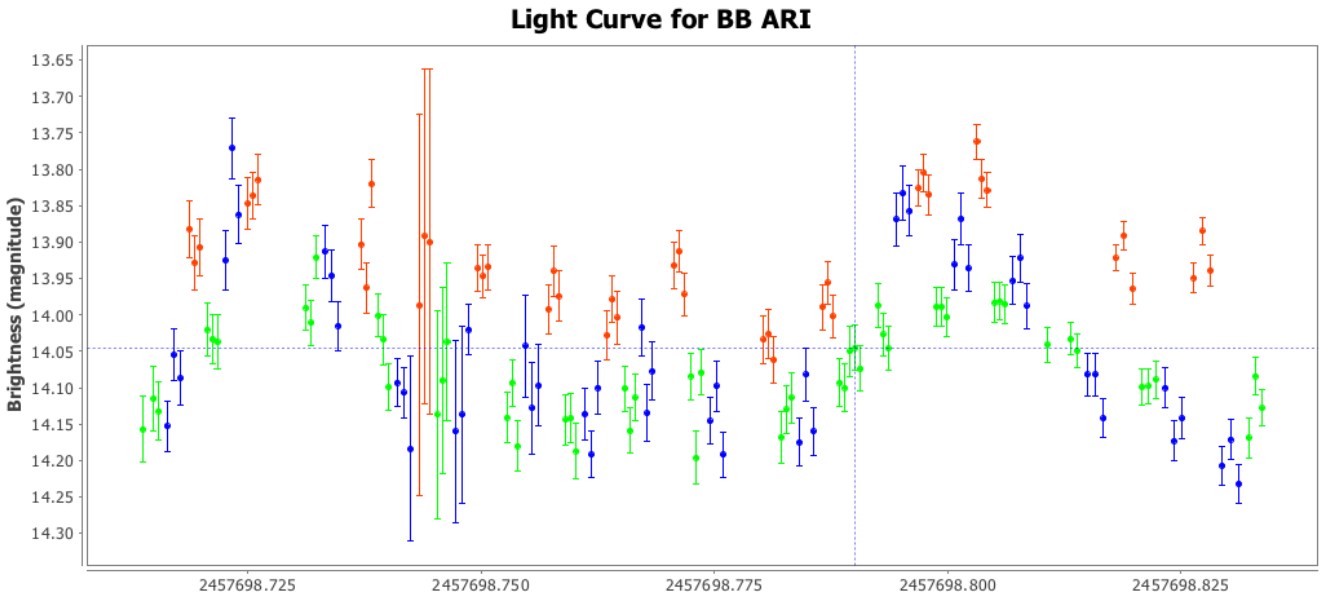
Observer W44 kept changing comp and check stars and also reported reference magnitudes. He fails to provide airmasses.

Observer T67 can get data with errors on the order of 0.02. But he will also observe when conditions drive the errors 3 and 4 times higher. These errors can be significantly larger than the magnitude differences between successive entries in his time series. Is there any point to this?

54 One can also question why a such a faint check star was used.
55 If the first observation actually took place in a 0.00001 JD window, that implies exposure+readout time of ~0.9 second.
56 A time series on 57761 terminates at airmass 18!

2. BB Ari

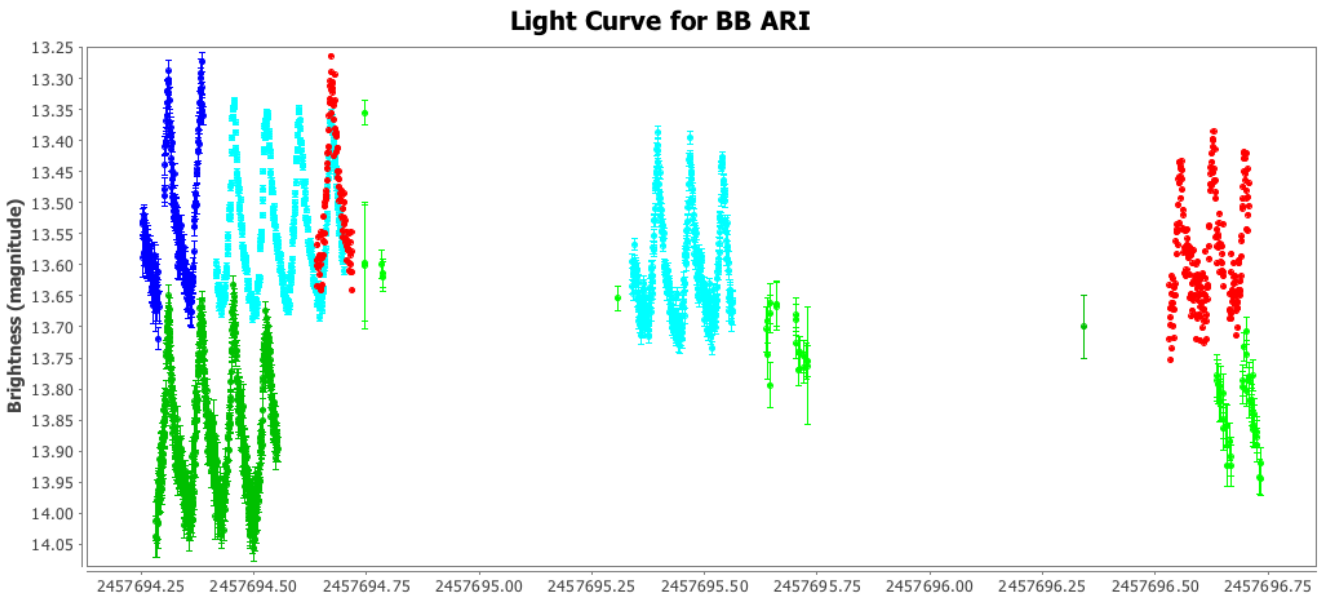
On RJD 57698, K0W is shooting B, V, and I in a curious pattern: three exposures of roughly one minute in one band, then advancing to the next band.[57] What is gained by this grouping? If he is trying to boost SNR by averaging, he should do it himself. [BVI data below in standard color-coding]



The series is clearly interrupted three times, at 0.73130, 0.79251, and 0.81068, but K0W made no notes about this. In the second case (crosshairs), it appears that the sequence goes haywire, with five V exposures in a row. In the last case, it appears that FJQ stopped to increase exposure times. There are also other timing anomalies, where it seems to take about two minutes more than usual to switch between filters. In addition, K0W lists his epsilon-B as 0.4, which is huge.

57 K0W does this on other stars, as well.

On RJD 57694-6, K0W has overlapping V data with four other observers, all shown here in different colors.



P20 **W0Y** **V5L** **K0W** **YY9**

P20 on 57694 is in reasonable agreement with the W0Y and V5L data, so we can be fairly confident of their magnitudes. The few K0W data points that day are arguably compatible. But at far right, K0W is quite faint in comparison to P20, and in the middle, K0W is arguably faint compared to W0Y. All these observers are submitting ensemble reductions, with P20 operating in tri-color green rather than true V (only K0W data are transformed).[58]

3. ASASSN-16NQ

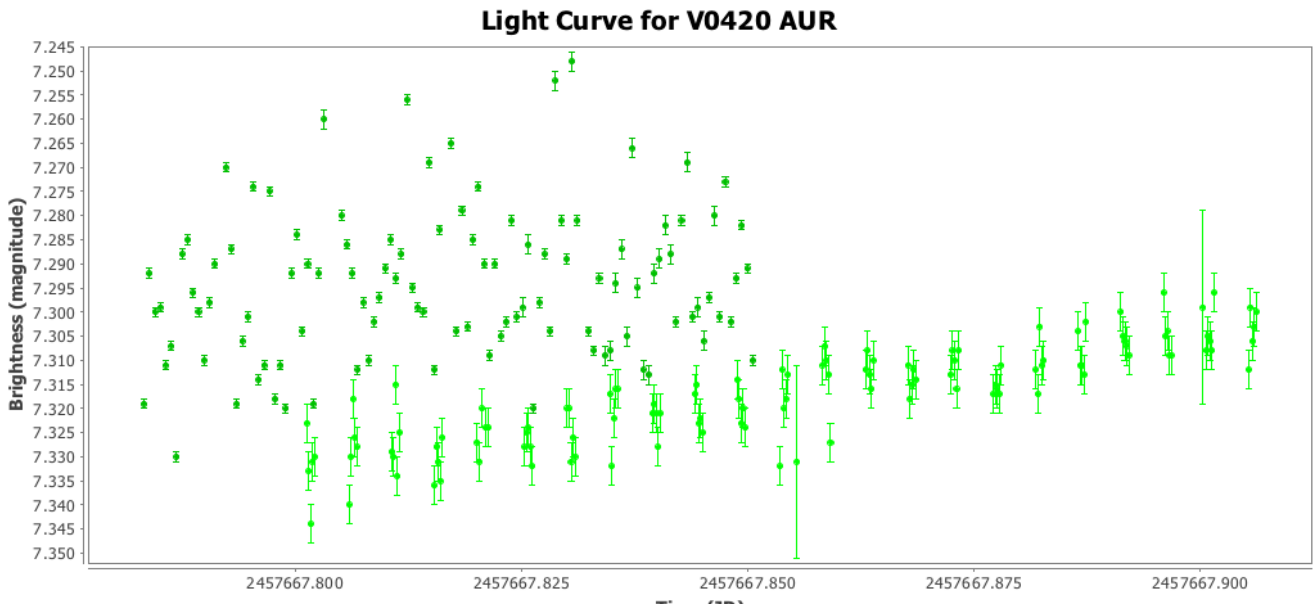
W0Y uses an APASS comparison for this faint star, but there appears to be no way to determine the comparison reference magnitude. The chart is given as "APASS" and the comp is identified as 4UC649-11058. But the APASS repository is not queryable by this identifier, only by RA/Dec. If coordinates for the target star are used to search for APASS stars in the vicinity, the list produced does not include identifiers of the type above.

58 The dim, dark green data on 57694 is YY9, again, operating unfiltered.

4. V420 Aur

Circa RJD 57666, observer U2D references chart 161007, which does not exist.

On 57667, observers I57 and P5N submitted V data, below. The modest magnitude difference between them could be attributed to lack of transformation, but the scatter in I57 is another matter. A best-fit-straight-line to his data gives an rms of about 15 mmag, while the BFSL for P5N has rms about 5 mmag. I57 and P5N are both experienced observers, so this is odd.

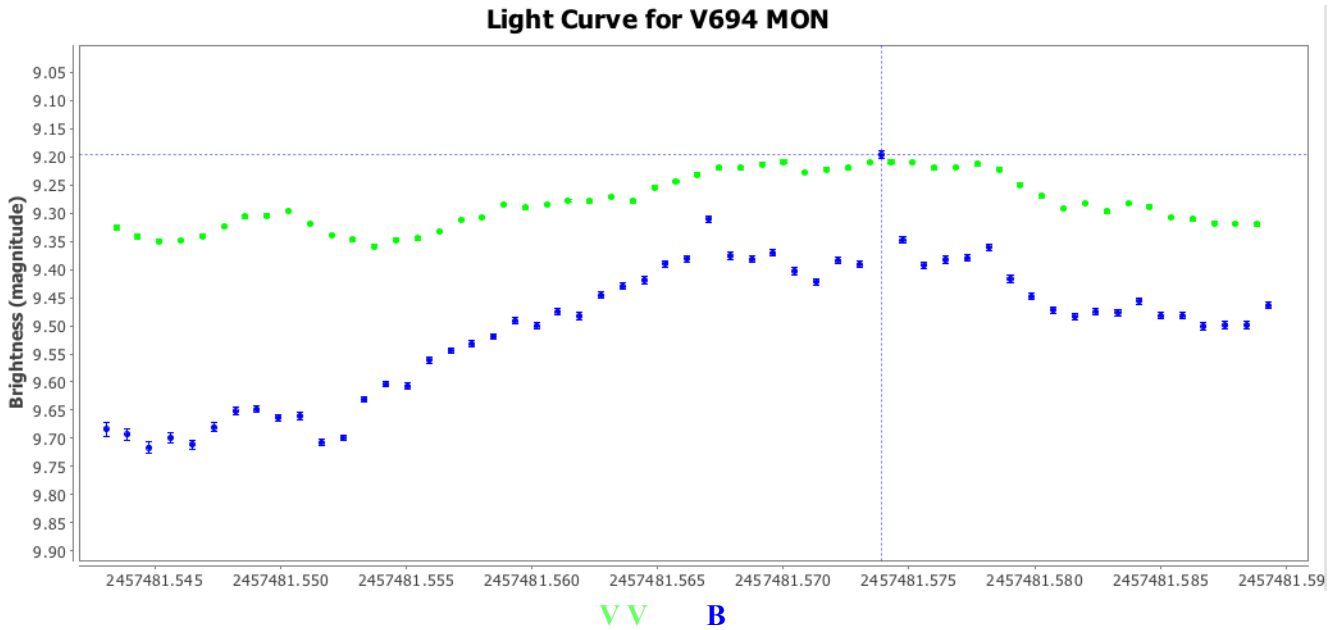


P5N I57

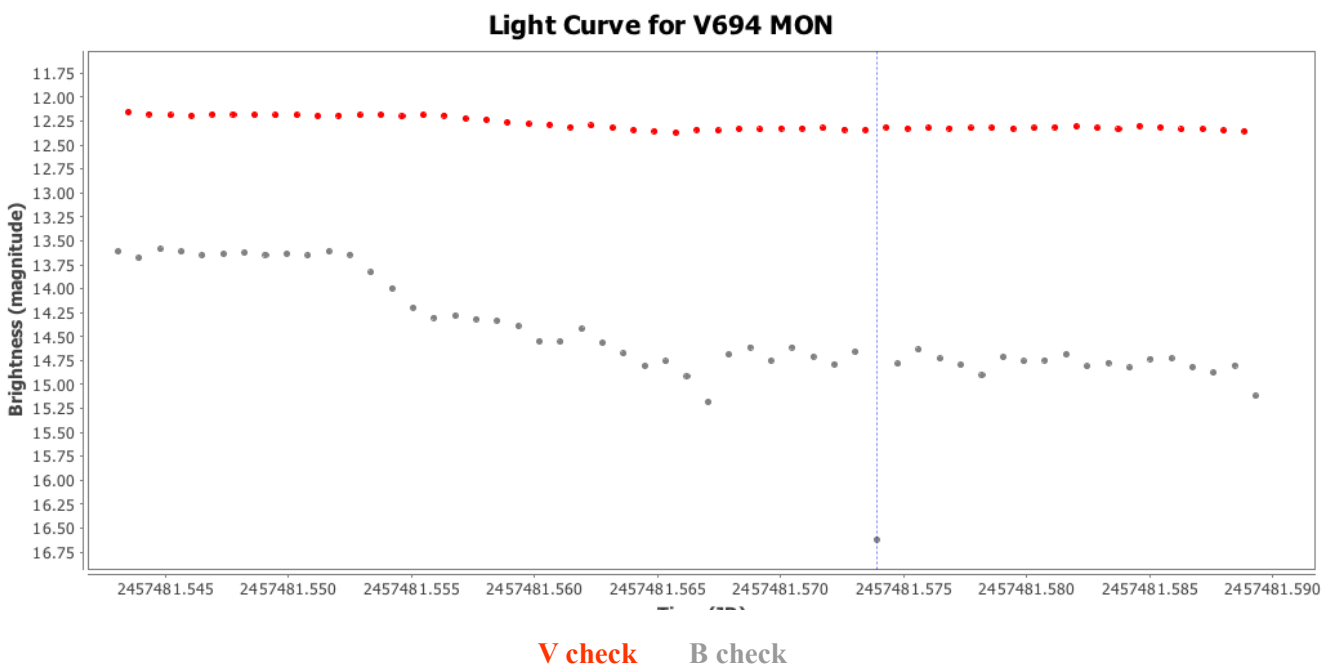
A communication with I57 revealed that he was using 5 second exposures on this bright star. He suspects that the scatter is due to scintillation.

5. V694 Mon

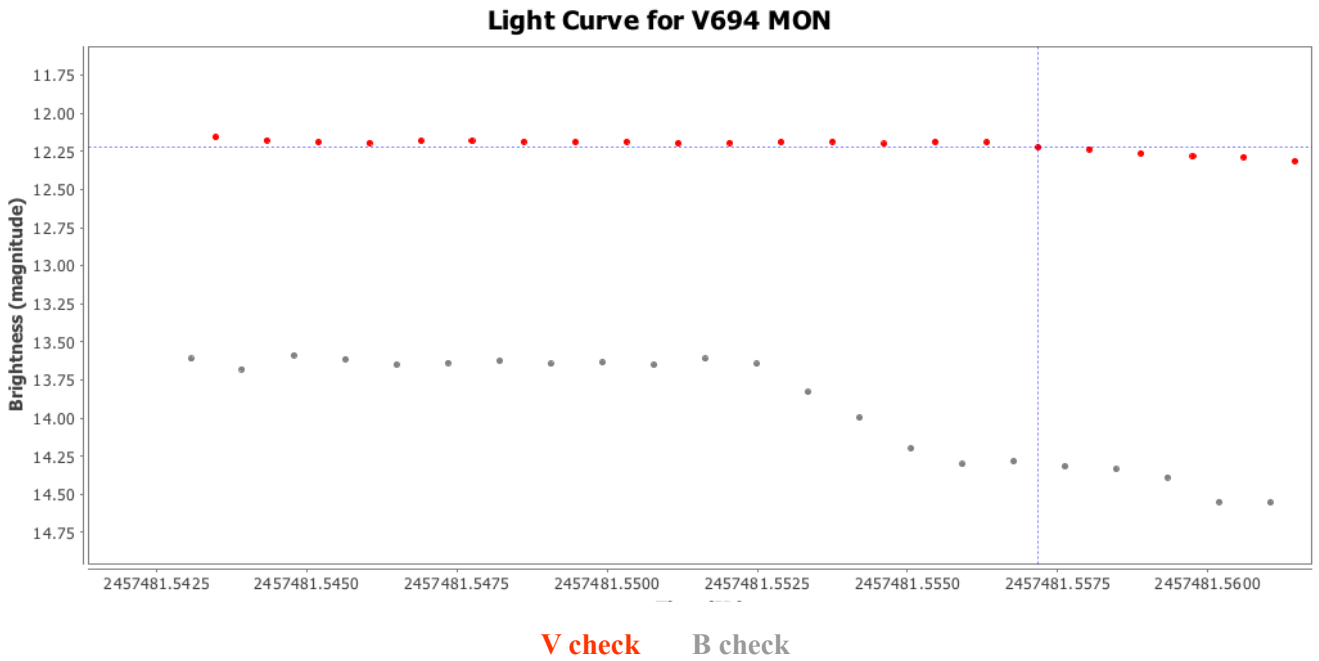
Consider the following light curve by LJ5, which has at least two overly-bright B magnitudes:



For the crosshair point, the check B magnitude is given as 16.618, while on either side it is about 14.65 and 14.78. Clearly something happened in B, but V was largely unaffected, the four surrounding check V magnitudes being 12.338, 12.341, 12.316, and 12.326. A complete graph of check magnitudes is revealing:



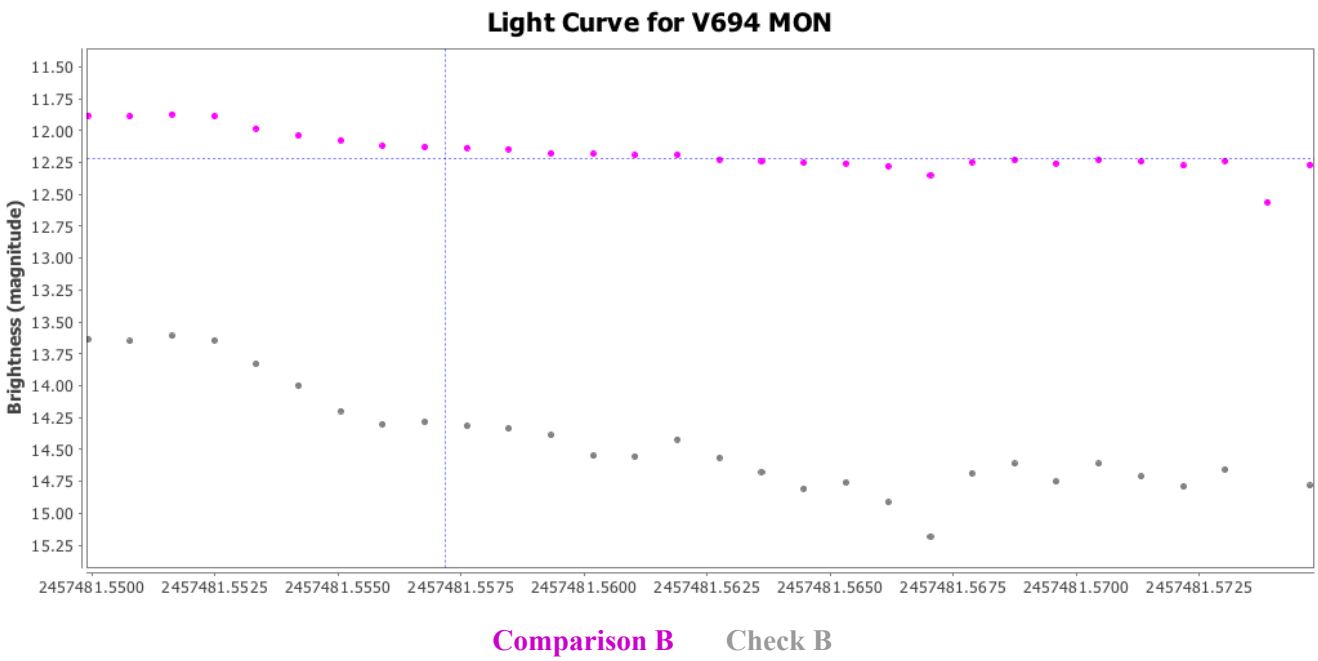
V band is suffering some degradation, presumably because of clouds or haze, and B band fares much worse, not only in terms of average attenuation, but of susceptibility to large, momentary drop-outs.[59] Zooming in, we see another effect:



The crosshairs are on what I consider the first "degraded" V magnitude (all prior points are brighter). But the degradation in B was *already* in progress: while V was holding steady, B had dropped by more than one-half magnitude. LJ5 did not note any transparency problems that night, but it is interesting to see that there is a 21 minute gap in his data where he might have noticed clouds and stopped observing.

The most aberrant B magnitudes of the program star are accompanied by aberrant B check magnitudes, so it is not to difficult to determine that they are worthy of exclusion. But without a graph of the check magnitudes, a researcher examining the data would not see the whole story. A particular question arises in the context of ensemble reduction: what would happen if this check star were part of the ensemble? Below, the B magnitudes of both the comparison and check stars are plotted:

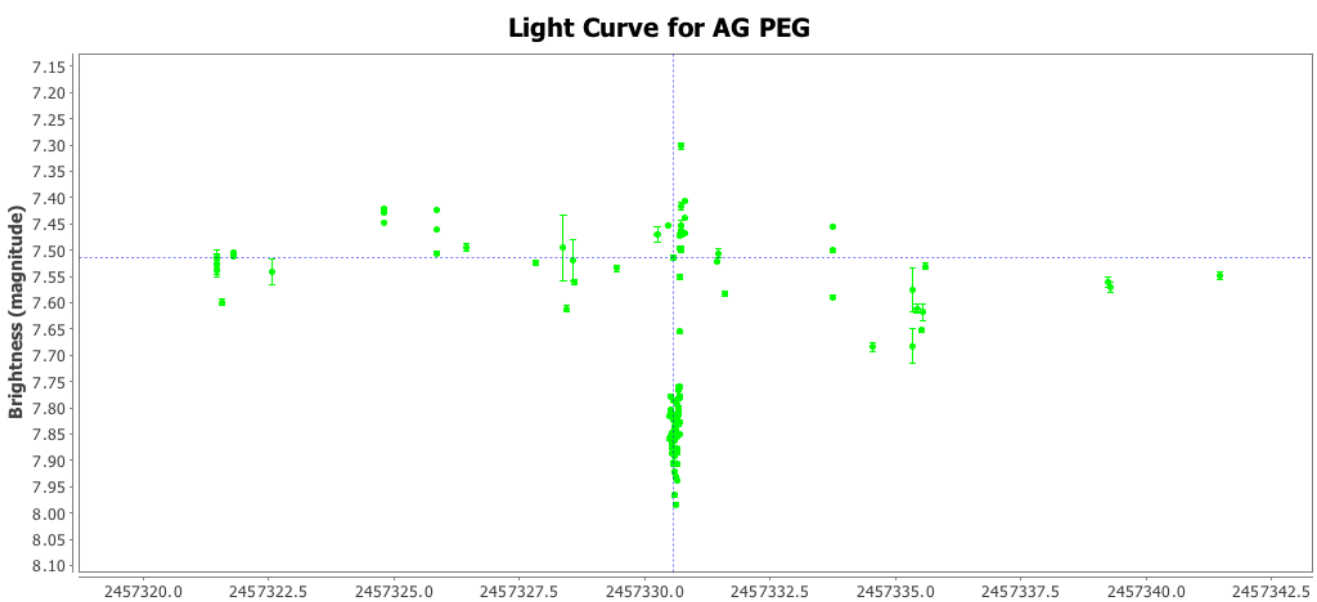
59 These are instrumental values, the nominal V=11.286 and B=12.359.



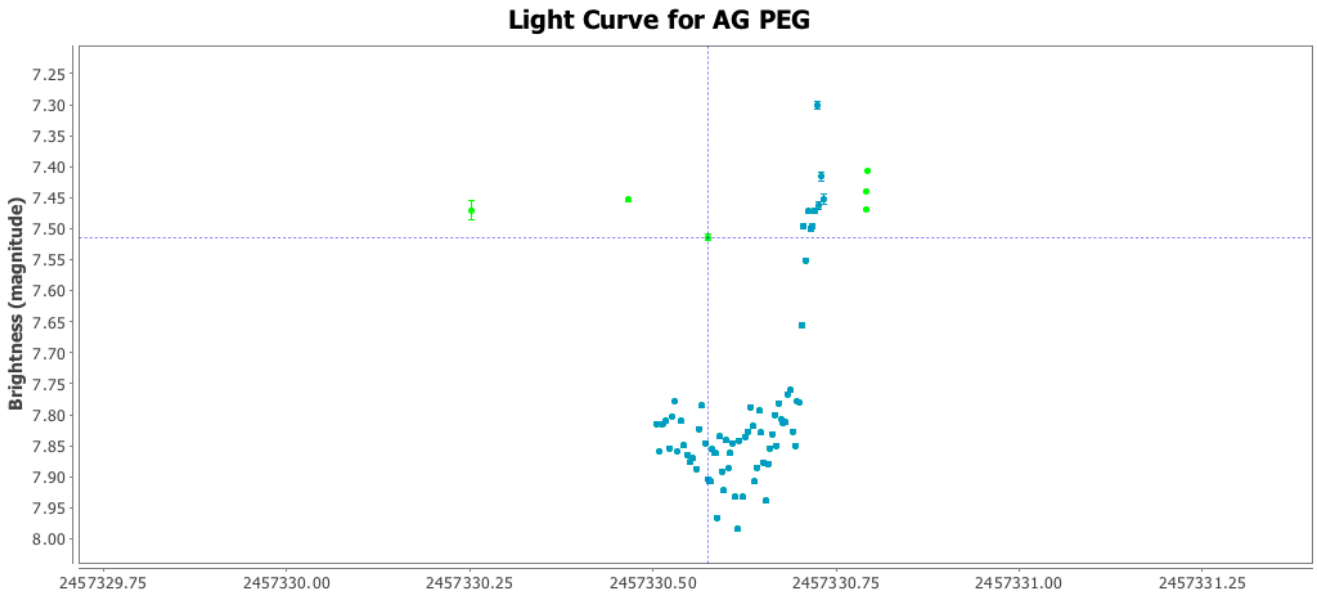
As you can see, ΔB grows considerably during the series. Does ensemble reduction software check that the relative magnitudes of the ensemble stars match expectations?

6. AG Peg

Below is a V band light curve including a single data point by experienced PEP observer SS5 (in crosshairs). The group of faint points below him is HH2:

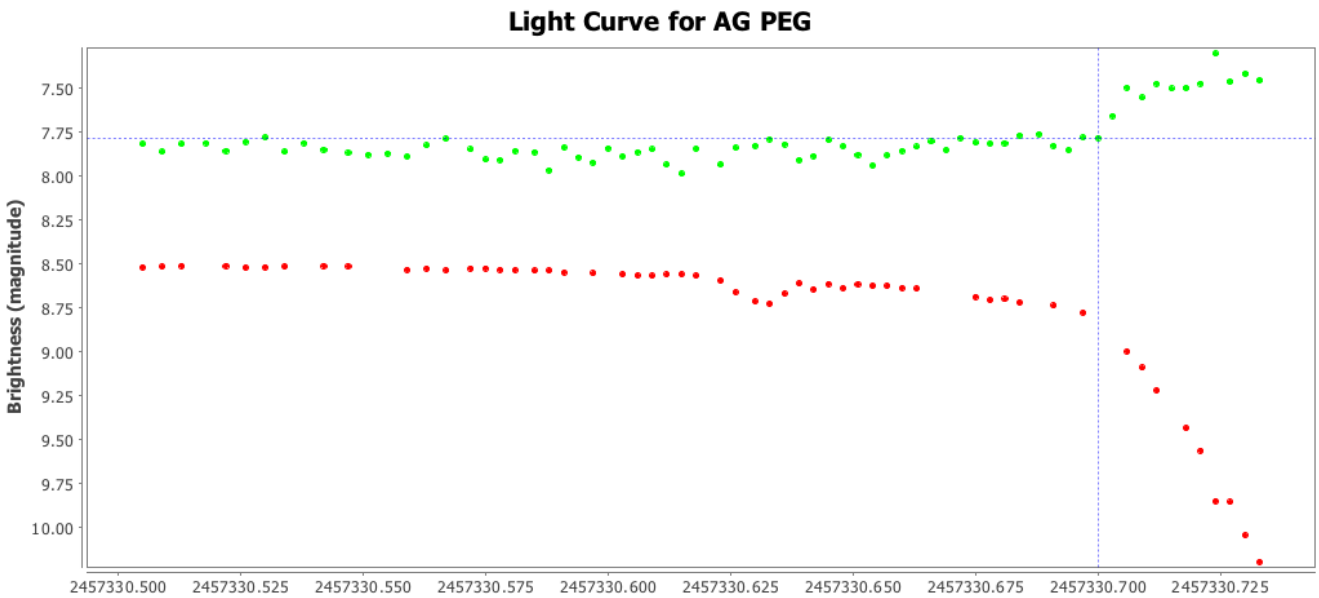


Zooming in, with HH2 now highlighted in pale blue, we have:



HH2

HH2 is not only too faint,[60] in general, but exhibits a wild shift brightward at the end of his series. What is happening? Below, his program and check star magnitudes are plotted, the latter in red. The check values have been shifted up by two magnitudes to compress the graphic, and the crosshairs are at the point just before the steep rise.



AG Peg **check**

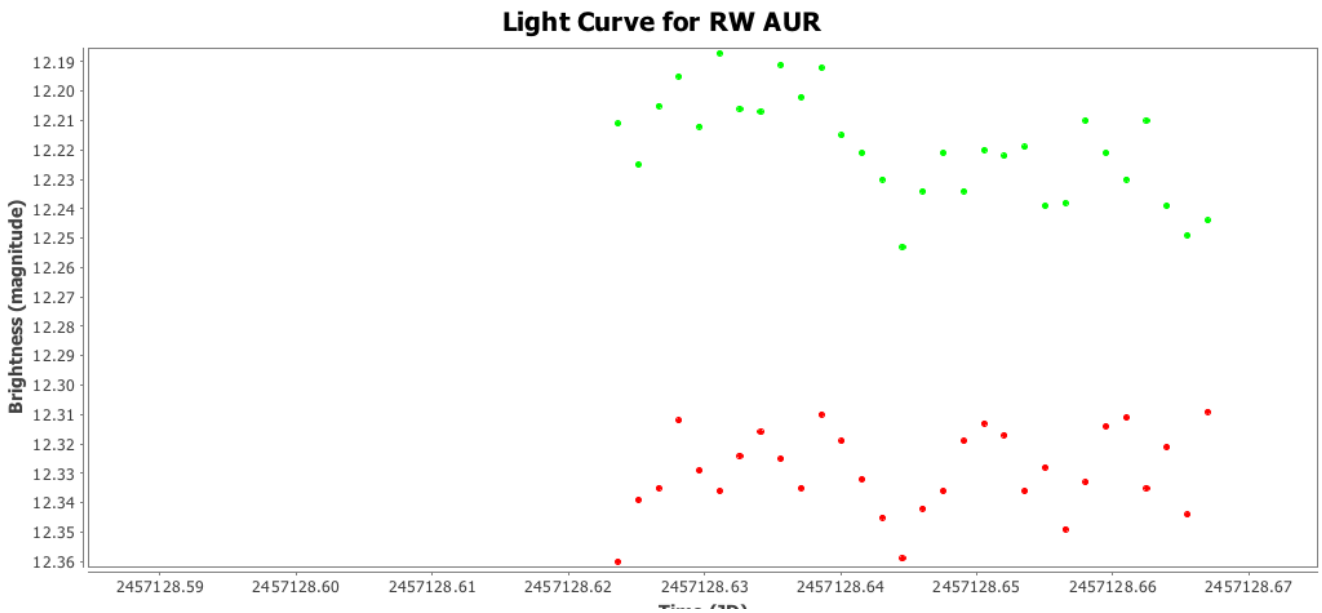
At the very beginning of this series, the airmass is listed as 1.154. At the crosshairs, it is 2.662. By the end, it is 4.376. A comparison ensemble was used, and differential extinction within the ensemble likely disrupted the

60 By about 0.3.

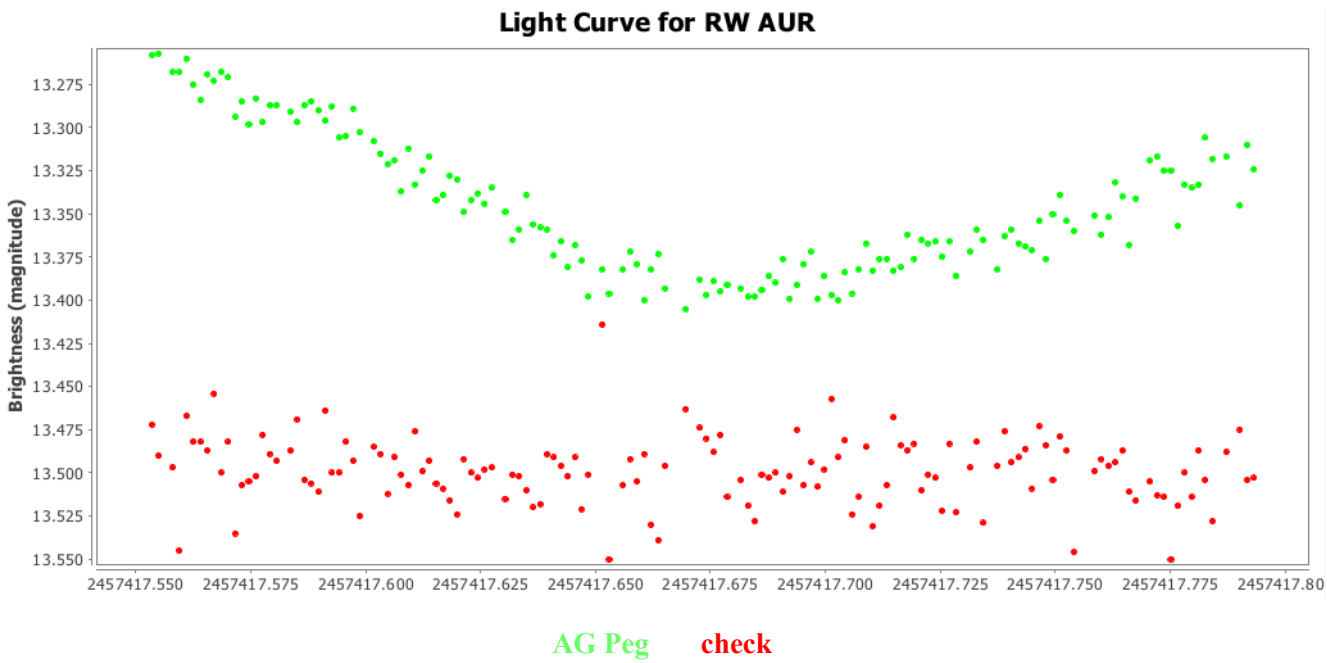
reduction. This may indicate that the reduction program is *not* checking for consistent instrumental magnitudes within the ensemble.

7. RW Aur

Below are V band data for K3X.



Something is clearly modulating the variable and check together. This is strange, because the variable is a reduced magnitude, whereas the check is supposed to be an instrumental magnitude. A single comparison star is used, so there is the possibility of its being variable, but another observing run with the same comparison (different check) some months later shows no mutual modulation, at least to my eye:



8. Conclusion

In the CCD records, we find problems similar to those in DSLR-land. Significant observer offsets, missing or incorrect metadata, extinction hazards, inappropriate CV targets (or comp stars), unnoticed transparency variations, reference magnitudes reported in place of instrumental magnitudes, questionable errors, and untraceable comparison stars. We also find scintillation effects and noticeable irregularities in magnitude reduction. If anything, this second half of the archive investigation was more difficult than the first. It surely scratches only the surface of the problems.

A further point, not regarding quality, as such, should be made regarding YZ Cnc. I presume the star is being followed so closely because of the Chandra TOO alerts. The investigator for the project requested observations, *one to a few times, widely spaced, per night*, but all of the problematic data discussed here came from timeseries . There might be some other research need served by high cadence sampling, but, more likely, people have an unrealistic model of the value of this activity. These data eat up AAVSO processing resources (especially if VPhot is involved) as well as storage space and waste the observer's effort.[61]

61 Ironically, however, time series data had useful diagnostic value in this study.