

# How I observe less-observed EBs

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April, 2020



Revised: 15 July 2020

Just one man's experience...

# Outline:

- What
  - Observations to make
  - Stars to observe
- When to observe them (ephemerides)
- How to find eclipses if ephem is wrong
- My personal “project”

# What observations?

- AAVSO is mostly about photometry
- But, the EB lightcurve (LC) is pretty much identical in every cycle (\*)
- The main goal of observing EBs is subtle changes in the timing of eclipses, via times of minimum (ToMs), which tell us about the nature of the orbits, and changes in those orbits, which in turn...
- So, the most useful observing method is time series photometry (many hours) through the eclipses, and determine the time of minimum of the LC. If eclipse too long for one night, stitch 2 nights, or ...

\* Exceptions of course: intrinsic variability, spots, modification of eclipse depths due to orbital precession, ... So, pure photometry of EBs is mostly going after second order effects, and hence must be planned carefully for that, probably with knowledge of the orbital phase, i.e. based knowledge derived from ToMs

# Which EBs to observe?

Two opposite approaches:

- Long-observed stars: continue legacy observations
  - Valuable to continue stars that already have a history
  - Easier to plan
  - Lower risk of failing to get an eclipse
- Stars with little obs history:
  - One observation could double the total observing history for this star!
  - Flesh out the population statistics
  - Enable future observers with better ephemerides,
  - Discover interesting behaviours meriting future work
  - Predictions can be quite inaccurate, can take multiple nights to get an eclipse

# Useful pre-requisite / background info:

If you are going to observe EB ToMs, it is very useful to be comfortable with O-C Diagrams. Some sources of info about them:

- The ppt from my presentation at the 2019 Annual Meeting, *and references therein*. Search the AAVSO website for “O-C Diagrams”, and one of the hits will be “GaryBillings\_HowTo\_OmC.pdf” (Note added July 2020: this powerpoint will also be made available on the AAVSO website, without having to search the Forums.)
- A paper by Roy Axelson “Methods for O-C...”, JAAVSO 42(2014):451ff
- Chapter 13 in “Variable Star Astronomy”, available under “Educational Materials” on the AAVSO website.

A very useful online O-C tool and EB ToM database (screen grabs shown in this presentation are of this website):

<http://var2.astro.cz/ocgate/?lang=en>

Note, enter star names with 4 digit GCVS number, including leading zero, e.g. “V0398 Cam”. You can enter your own data, and have it plot on the O-C diagram.

Another site, with near-term predictions:

<http://www.as.up.krakow.pl/ephem/>

This site uses its own elements, updated with the latest data they have.

# Basics of periodic phenomena:

Based on the equation of a straight line:

$$y = mx + b$$

$$T_E = PE + T_0$$

$$T_E = T_0 + P \times E$$

E.g., GCVS elements for V398 Cam:

$$T = 2451615.633 + 2.0872 \times E$$

Index (cycle) number of event

Period

Time of event 0, the “epoch”

Time of event E

# What phases have you observed?

As an Excel equation:  
= mod( T - epoch, period)/period



Turn the equation around:

$$\varphi = \text{decimal part of } \{ (T - T_0) / P \}$$

Use this to determine what phases you've observed (in fractions of a cycle).

For searching: Start at 0 (the expected time of eclipse), and if not found, gradually observe phases on either side until eclipse found.



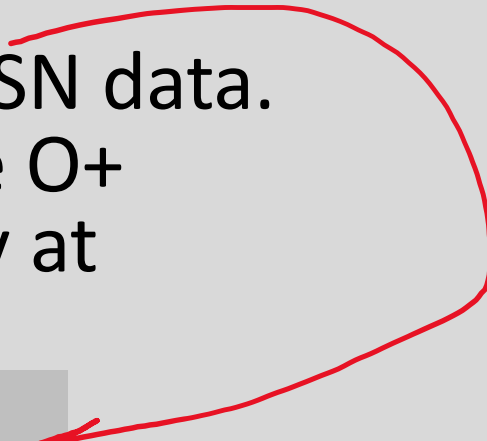
# My own observing:

- Times of minimum via all-night time series, to revise elements for future predictions, and identify “interesting stars”
- Less commonly observed stars:
  - I use the Otero+ list (spreadsheet from AAVSO EB pages). It matches my mag range, some unobserved since discov.
- Stars in Cam, Dra, Cep (+ UMa, UMi)
  - Their high declination suits my latitude (51 N) and my observing setup (can observe through nadir)
- Longer periods (3+ days)
  - Less popular
  - But when ephemeris is off, a whole night might show no variation at all (I recently started using ASAS-SN LCs to “home in” on eclipses)

# How I plan a night:

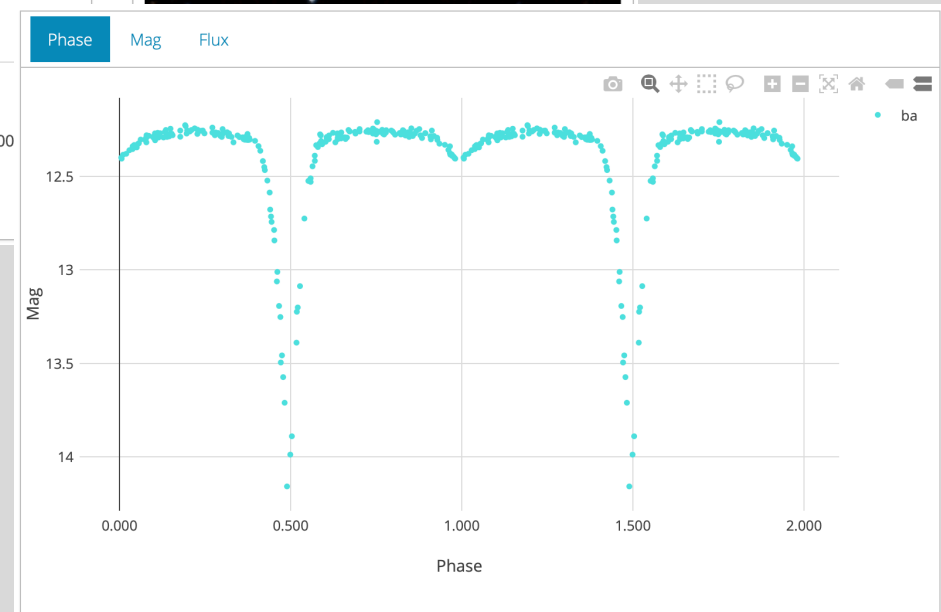
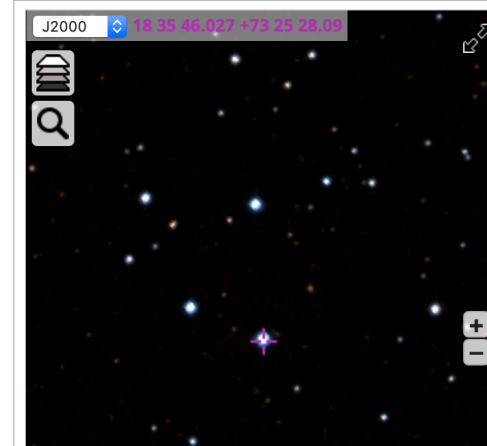
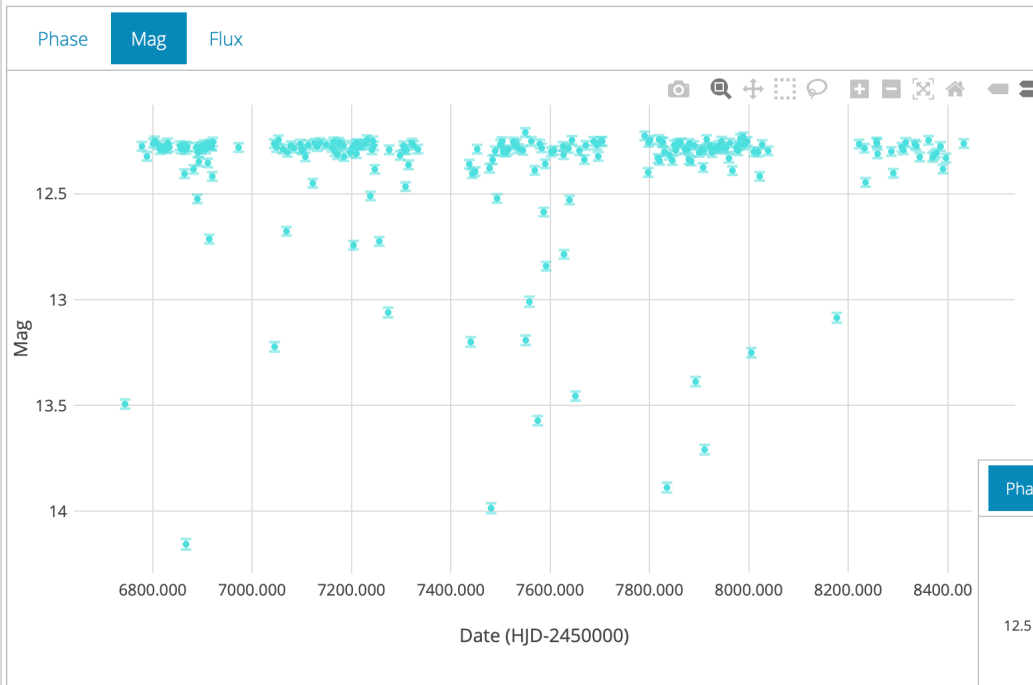
- I use Otero+'s elements and a script to id targets for a night (I list all predictions for a chosen constellation, but could easily select on RA, dec, mag range, period etc)
- Check my previous observations!
- Check Cracow and BRNO site's O-C diagrams, to see if they show recent observations
- Do sanity check on prediction, e.g. using BRNO "O-C Gateway". Enter the prediction as "user data", see what the O-C would be.
- If no obs'ns since discovery, check ASAS-SN data. Download their data to spreadsheet, use O+ period, and modify epoch to put primary at phase=0, make a prediction for tonight...

<https://asas-sn.osu.edu/variables/lookup?utf8=✓>  
(Needs 4 digit GCVS numbers)



# ASAS-SN

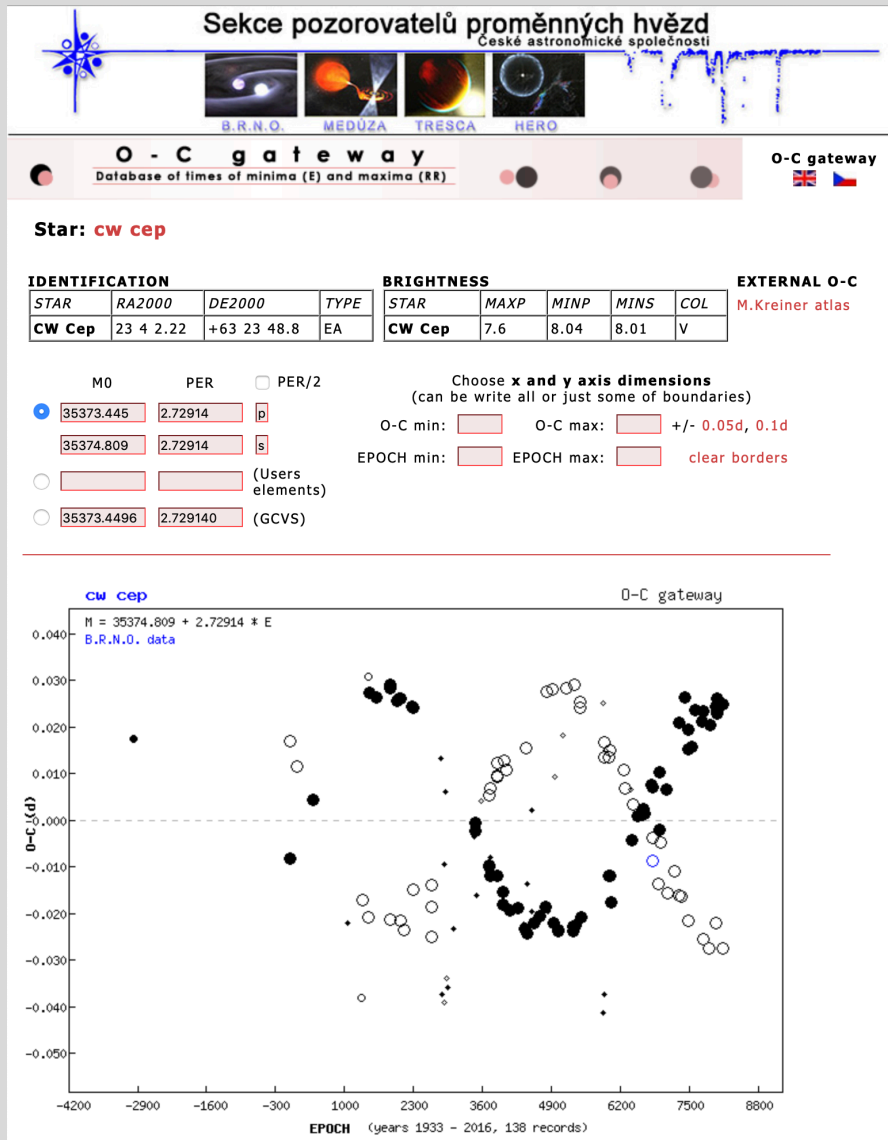
Mean VMag	Amplitude	Period	Type
12.37	1.26	1.204212	EA
Classification Probability	LKSL Statistic	RFR Score	Epoch (HJD)
0.999	0.02	0.99	2457910.94494



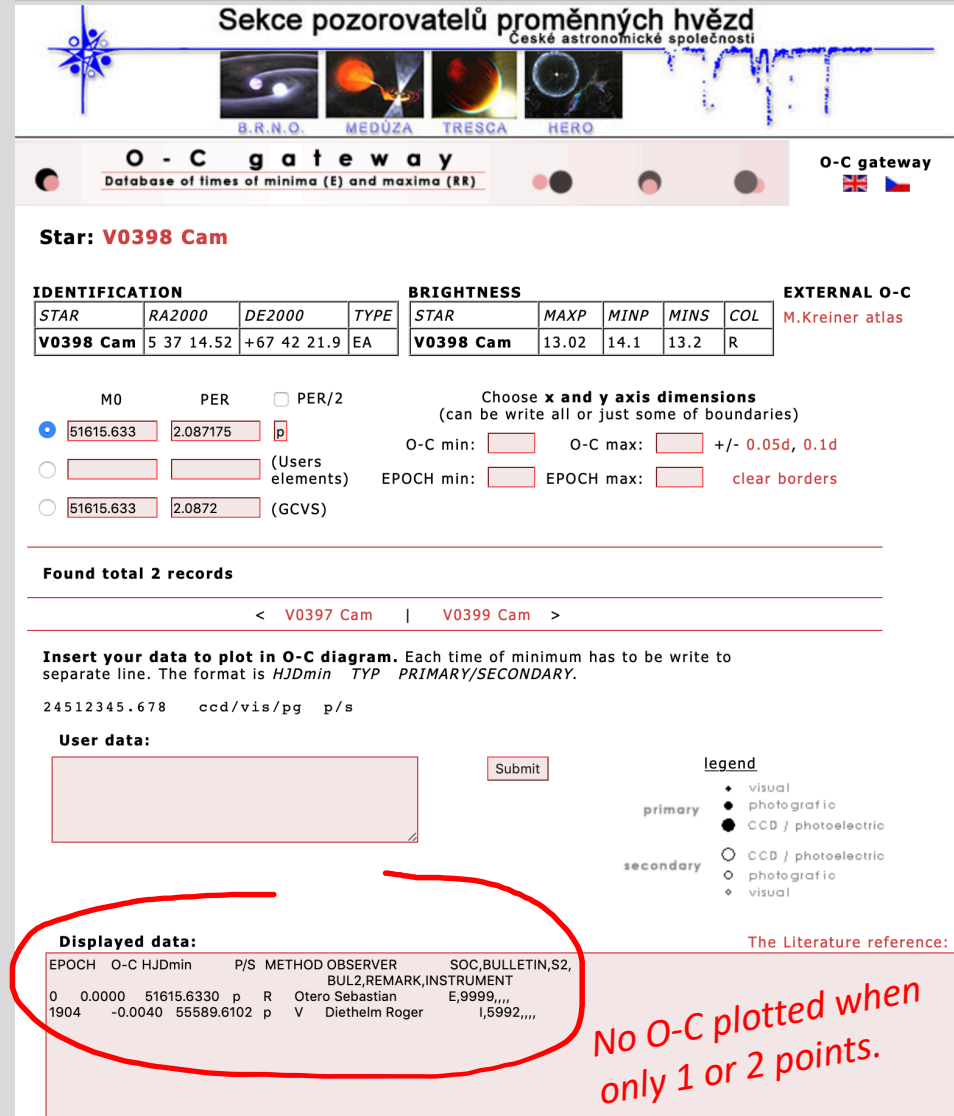
- ASAS-SN data for V407 Dra. 214 observations over the last 4 years.
- For some stars, the ASAS-SN website does not offer a phased LC, but you can download the unphased data and do it yourself.

# Two cases, B.R.N.O. O-C Gateway

## CW Cep – long observational history



## V0398 Cam – only the discovery and one other observation



# V0398 Cam, B.R.N.O. O-C Gateway

Add one new observation:

Star: **V0398 Cam**

## IDENTIFICATION

STAR	RA2000	DE2000	TYPE
V0398 Cam	5 37 14.52	+67 42 21.9	EA

## BRIGHTNESS

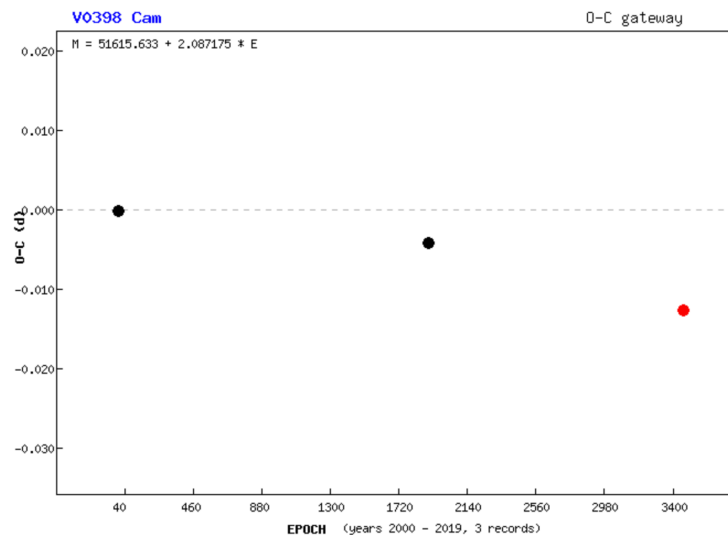
STAR	MAXP	MINP	MINS	COL
V0398 Cam	13.02	14.1	13.2	R

## EXTERNAL O-C

M.Kreiner atlas

M0 PER ☐ PER/2  
☒ 51615.633 2.087175 p  
☐ (Users elements)  
☐ 51615.633 2.0872 (GCVS)

Choose x and y axis dimensions  
(can be write all or just some of boundaries)  
O-C min: O-C max: +/- 0.05d, 0.1d  
EPOCH min: EPOCH max: clear borders



< V0397 Cam | V0399 Cam >

Insert your data to plot in O-C diagram. Each time of minimum has to be write to separate line. The format is *HJDmin TYP PRIMARY/SECONDARY*.

24512345.678 ccd/vis/pg p/s

## User data:

2458847.6817 ccd p

Submit

## Legend

- primary
  - + visual
  - photographic
  - CCD / photoelectric
- secondary
  - CCD / photoelectric
  - photographic
  - ◆ visual

## Displayed data:

EPOCH	O-C HJDmin	P/S	METHOD	OBSERVER	SOC,BULLETIN,S2, BUL2,REMARK,INSTRUMENT
0	0.0000	51615.6330	p	R	Otero Sebastian E,9999,,,
1904	-0.0040	55589.6102	p	V	Diethelm Roger I,5992,,,

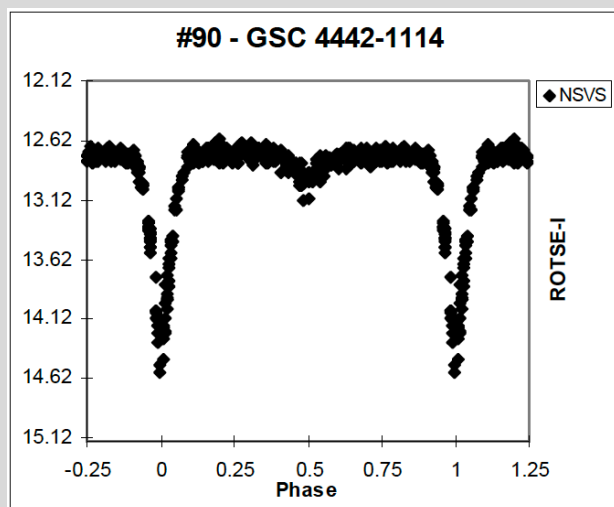
User data:  
3465 -0.0127 58847.6817 p ccd user-data

The Literature reference:

Shows that the period BRNO is using is slightly off, but not too bad. My 2019 obs'ns came in 0.013 days early (23 m).

# V0407 Dra, B.R.N.O. O-C Gateway

The literature only shows Otero's discovery obs'n, using 1999 NSVS data. I find the eclipses 3 h later than the ephemeris, and the period estimate needs to be refined.



OEJV 91

Star: **V0407 Dra**

## IDENTIFICATION

STAR	RA2000	DE2000	TYPE
V0407 Dra	18 35 46.04	+73 25 29.5	EA

## BRIGHTNESS

STAR	MAXP	MINP	MINS	COL
V0407 Dra	12.75	14.6	13	R

## EXTERNAL O-C

M.Kreiner atlas

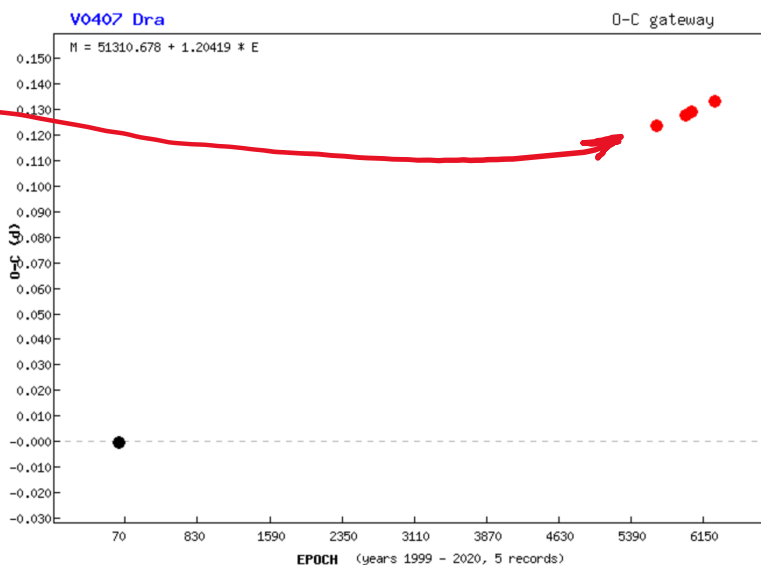
M0 PER ☐ PER/2

☒ 51310.678   (Users elements)

Choose **x and y axis dimensions**  
(can be write all or just some of boundaries)

O-C min:  O-C max:  +/- 0.05d, 0.1d

EPOCH min:  EPOCH max:  [clear borders](#)



< V0405 Dra | V0413 Dra >

**Insert your data to plot in O-C diagram.** Each time of minimum has to be write to separate line. The format is *HJDmin TYP PRIMARY/SECONDARY*.

24512345.678 ccd/vis/pg p/s

## User data:

2458122.9043 ccd p  
2458505.8406 ccd p  
2458576.8895 ccd p  
2458871.9201 ccd p

[Submit](#)

## legend

- visual
  - fotografic
  - CCD / photoelectric
  - CCD / photoelectric
  - fotografic
  - visual
- primary
- secondary

## Displayed data:

EPOCH	O-C HJDmin	P/S	METHOD	OBSERVER	SOC,BULLETIN,S2, BUL2,REMARK,INSTRUMENT
0	0.0000	51310.6780	p	R1	Otero Sebastian
User data:					
5657	0.1235	58122.9043	p	ccd	user-data
5975	0.1274	58505.8406	p	ccd	user-data
6034	0.1290	58576.8895	p	ccd	user-data
6279	0.1331	58871.9201	p	ccd	user-data

The Literature reference:

# Summary

- Fun for everyone: “legacy” stars, and less-observed stars
- For the least-observed stars, “detective work” is often required
- Be comfortable with the linear ephemeris equation, and O-C diagrams
- There are some online tools and data sources to complement your work...