

SODIS
Stellar Occultation Data Input System
Observer Documentation



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About this document

This document describes how to report observations to SODIS. It also shows how SODIS works and gives some advice on data reduction. For observers in a hurry, it is sufficient to study [Chapter 1](#), but all other chapters are recommended to be read as well.

The document is intended for the internal use of the SODIS community, it is not released for general publication.

As SODIS is relatively new and rapidly evolving, this document is still a work in progress and will be adapted as needed. For the same reason, not all images and information are always up to date with the latest software versions.

The place to discuss this document and users' experiences with SODIS is the SODIS Forum <https://forum.iota-es.de/index.php>.

URLs are only mentioned in exceptional cases in the text, most of them can be found in [Chapter 4](#). Observer names and positional data have been largely anonymised, but in some cases this was not possible for content reasons (then the data come from SODIS and Occult4). All data and examples used in [Chapter 3](#) are from the author.

Acknowledgements

The author would like to thank the SODIS development team and also the reviewer teams, the software developers/maintainers of Occult, OccultWatcher/OWC, Tangra, PyMovie/PyOTE and SharpCap, all colleagues for useful discussions and last but not least the observers.

Change log

V 21-03-2023 First version (in this format)

C. Weber

1 How to report to SODIS

1.1 SODIS overview

SODIS (Stellar Occultation Data Input System) is the IOTA/ES data collection system for observations of occultations by minor planets and other solar system bodies. The need for the development was due to the discontinuation of the Euraster service by E. Frappa on 31-12-2022. SODIS was created by a team of IOTA/ES, the software developer is E. Tunsch. SODIS relies on a database managed by IOTA/ES ([Figure 1.1](#)). [Figure 1.2](#) shows the dataflow of the SODIS system.

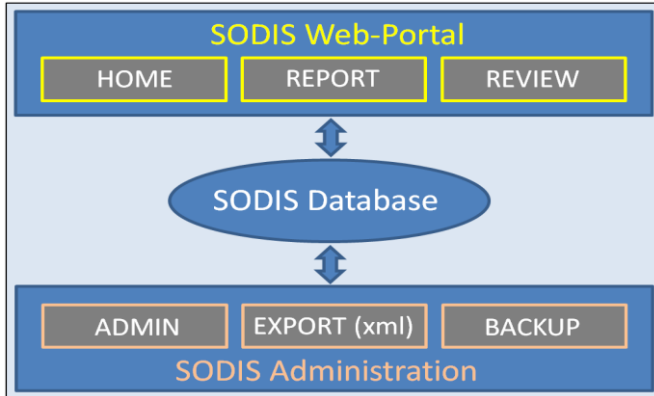


Figure 1.1. SODIS architecture.

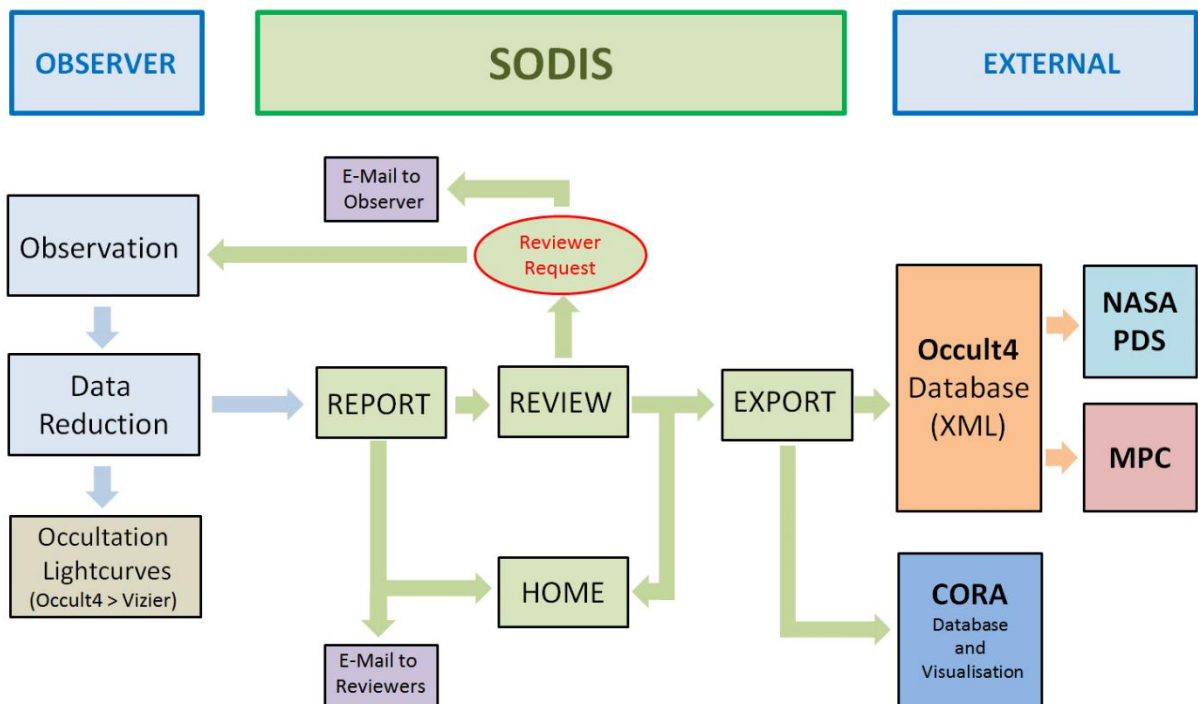


Figure 1.2. SODIS dataflow (schematic).

After data reduction by the observer, the observations are entered into the SODIS system via the REPORT page. The reports are then displayed on the HOME page and are marked with a yellow sign (for "not yet reviewed"). The HOME page ([Figure 1.4](#)) is publicly accessible without login (but for using the VIEW button login is required).

An account is required for all other activities at SODIS (and also for the SODIS forum). Furthermore, SODIS users must have verified their email accounts in order to receive emails from the SODIS system (e.g. in the case of a reviewer request to an observer), see [Figure 1.3](#).

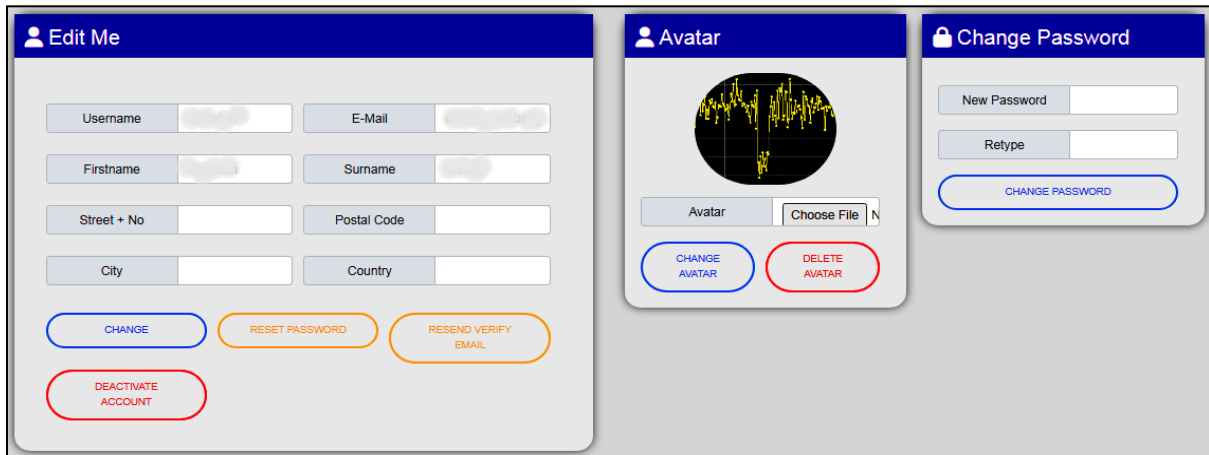


Figure 1.3. The SODIS user account settings are available via the avatar at the top right of the SODIS website. The email verification is done with the RESEND VERIFY EMAIL button.

When a new observation is entered, the reviewers receive an e-mail with a corresponding note (including the country code CC). The REVIEW page ([Figure 1.5](#)) allows reviewers to check the observation and contact the observer (reviewer request) if there are any unanswered questions, as well as delete an observation if necessary. After a successful check by the reviewers, the observations are marked green on the HOME page and the review process is completed. In the future, M. Kretlow’s CORA (Collaborative Occultation Resources and Archive) will parse the SODIS database and display the results.

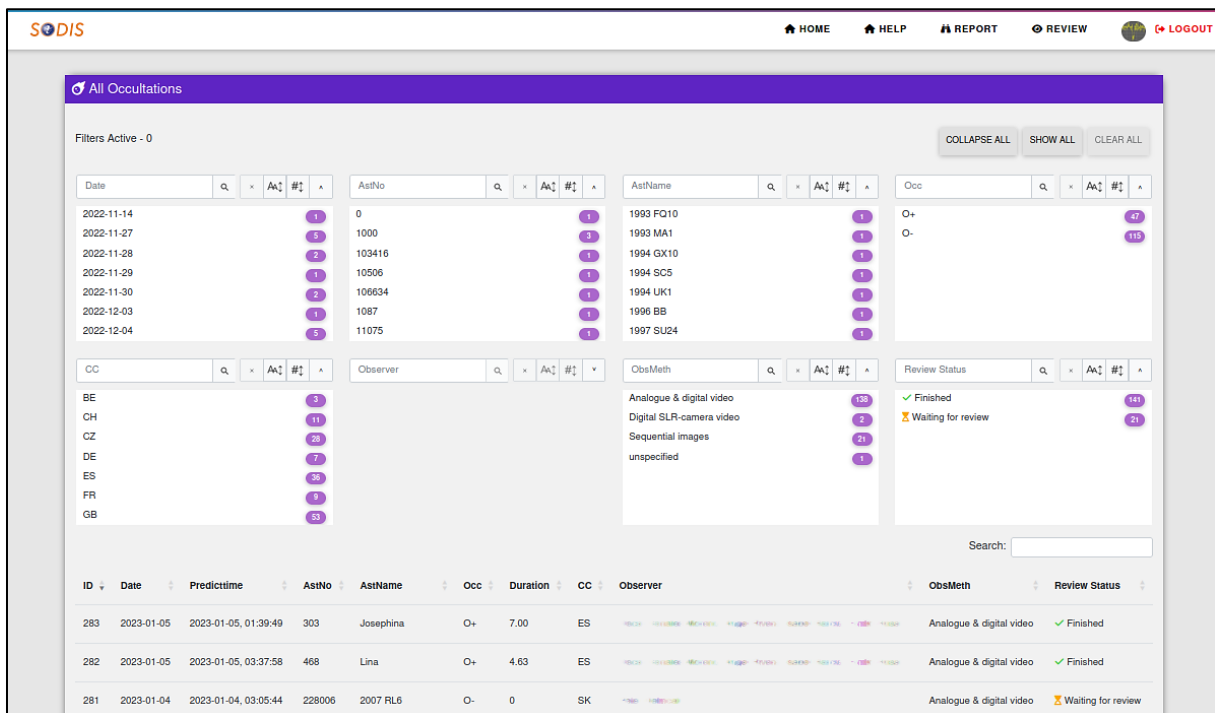


Figure 1.4. SODIS HOME page showing several filters and reviewed (green hook) and not yet reviewed (yellow sandglass) observations. For logged in users, there is also a VIEW button (not shown) on reviewed reports that can be used to view the entire record.

ID	Date	Predicttime	AstNo	AstName	Occ	Duration	CC	Observer	ObsMeth	
110	2022-11-30	2022-11-30, 20:46:55	171688	2000 SP18	O-		CZ		Analogue & digital video	REVIEW
109	2022-11-27	2022-11-27, 23:59:52	5813	Eizaburo	O-		ES		Analogue & digital video	REVIEW
108	2022-11-27	2022-11-27, 20:49:50	510097	2010 OF126	O-		ES		Analogue & digital video	REVIEW
107	2022-11-27	2022-11-27, 19:13:01	106634	2000 WY131	O-		ES		Analogue & digital video	REVIEW

Showing 1 to 4 of 4 entries

Previous [1](#) Next

Figure 1.5. SODIS REVIEW page, showing observations to review.

For SODIS users, it is very important to realise that there is a fundamental difference between the previous (partly relatively open) reporting form on Planoccult (and E. Frappa’s Euraster management) and the requirements of SODIS. Because the observations are exported later by the SODIS administration to D. Herald to be entered into the Occult4 database (the official worldwide IOTA repository), the SODIS input mask is strictly oriented to the requirements of Occult4. Data entries that the SODIS REPORT page does not contain or request are not possible.

1.2 Occult4/SODIS classification of observations

The following section describes the classification of occultation events.

- **Detection of an event (positive observation)**

Required is a typical occultation pattern (usually abrupt transitions and a flat bottom, apart from special effects such as diffraction or the presence of an atmosphere) that is not found repeatedly in the light curve or in the light curves of comparison stars. Additional requirements are a drop that more or less matches the prediction (unless it is the detection of a component of a multiple star) and an event time that is within the 3-sigma uncertainty of the prediction (unless there is clear evidence of an issue with the prediction, e.g. due to a multiple star or a previously unknown satellite). As a rule of thumb, an occultation event should have at least 3 data points, but there may be exceptions, see [Chapter 3.3.3](#).

Depending on the event type observed, the Occult4 event codes can be “D”, “d”, “M”, “G”, “g”, “N” for disappearance and “R”, “r”, “M”, “B”, “b”, “N” for reappearance (see [Figure 1.6](#)). The observer does not have to deal with the letter codes, SODIS does that automatically.

Note: Occult4 knows some additional special codes, which intentionally do not appear in the SODIS REPORT mask because of their relative complexity: "m", "n", "e", "f". (see [Chapter 5.1](#) for an explanation of these codes).

D	Main Star	D Time
Duration		
R	Main Star	

Main Star	D	R
Second Star	d	r
Non Detection	M	M
Satellite Main Star	G	B
Satellite Second Star	g	b
Ring	N	N

Figure 1.6. D and R SODIS (and Occult4) event classification on the SODIS REPORT screen. Added: Event codes in red for disappearance and in green for reappearance.

It is clear that with a single observation one cannot decide which component of a multiple star has been occulted, whether it is a satellite or even a ring. When determining orbits from single chords, the MPC requires that the chords be aligned with the centre of the asteroid, even for short chords relative to the asteroid diameter.

For multiple events (double stars, secondaries), several reports must be submitted.

- **Non detection (negative observation)**

No event according to the above criteria was recorded, SODIS classification: “Non Detection”, event code “M” ([Figure 1.6](#)). No information needs to be provided in the SODIS REPORT fields “D Time”, “Acc_D”, “Duration”, “R Time” and “Acc_R”. The common interpretation is that the object has not passed in front of the star (relative to the observer's current position). Provided the (correct) star has been recorded with sufficient SNR and time resolution, a non detection can also be very important, e.g. to limit the shape of an object (“near miss”).

However, there can be situations where an occultation occurred but was not detected e.g. due to a bad SNR, insufficient time resolution compared to the predicted drop duration or an insufficient limiting magnitude of the telescope/camera recording chain. In other words, even in the case of non-detection, the technical means must have been sufficient (if these conditions had not been met, the recording would have been *unreliable, not negative*).

Note: Single/multi chord non detection observations are stored in SODIS, but not exported to the Occult4 database (unless at least one positive observation is registered).

- **“Uncertain”**

The Occult4 database and consequently SODIS do not know "uncertain" observations (apart from possible comments in the observer XML field "Conditions"), but there may be cases where an observer has problems deciding whether his observation is a real event. In such situations, the observer should send a report with a related comment. The reviewer checks the data and may contact the observer to clarify the situation. If the observation is classified as a real event, the reviewer will probably use the available weighting and plot options ([Chapter 2.3](#)), otherwise the observation may be a non detection or is deleted if the data is unreliable.

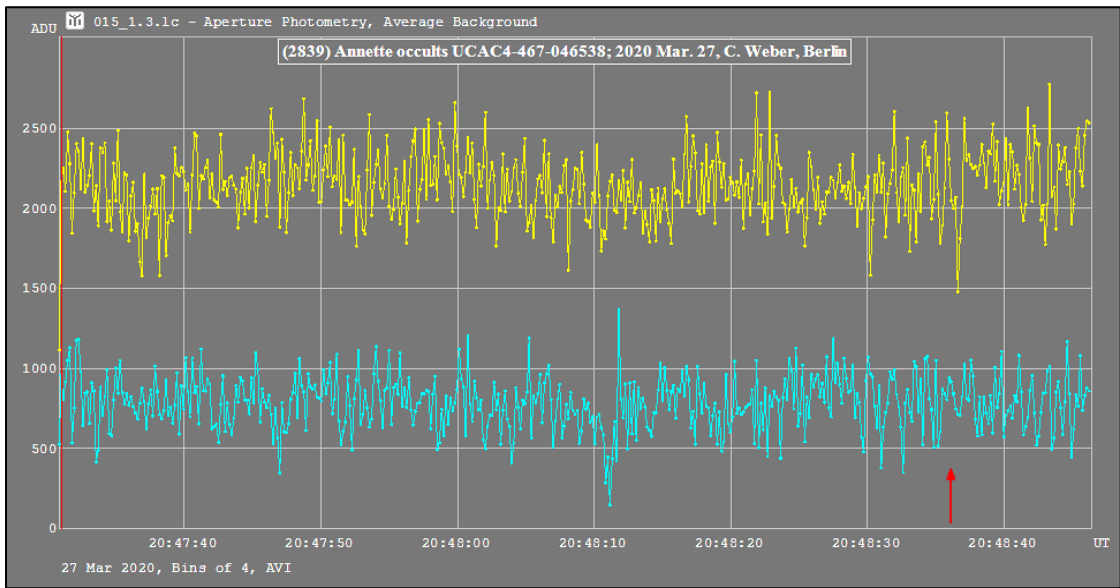


Figure 1.7. Example of an uncertain observation: The red arrow marks the predicted time of a 3.1 mag drop of 0.6 s duration. See text for an explanation.

[Figure 1.7](#) shows an example of a recording that was classified as uncertain on Euraster (not published there because it was a single observation). There are several reasons for this classification. The “drop” found (at about 20:48:12 UT) is not well formed, doesn’t reach the predicted 3.1 mag and is outside of 3-sigma in time. In addition, there are similar patterns in the yellow reference lightcurve. In SODIS this would be a non-detection (probably with the comment "suspicious drop at ..."). As it is a single observation, the observation would be saved in SODIS but not exported to Occult4.

Events with **only one or two data points** are a special case. Depending on the actual situation, there may be reasons not to exclude them immediately (at least if there are other detections) but probably no astrometry will be derived. For a single point example data reduction see [Chapter 3.3.3](#).

One can find a single point example regarding the event “(5511) Cloanthus occults UCAC4 405-072730 on 2021-Jun-16 at 23:06 UT”. The related XML Occult4 database section for the single point observation looks as follows:

```
<Conditions>||0.80||Uncertain. Single frame event.</Conditions>
<D>23 6 15.74|D|0.64||0| </D>
<R>23 6 17.02|R|0.32||0| </R>
```


Note: In the example above, both D and R times are “0” (zero) weighted, excluding them from the astrometric solution, and under “Conditions” a comment is added.

Because in the example there is no plotcode set (empty field after the weighting field) the observation will be plotted in the Occult4 asteroid observations editor ([Figure 1.8](#)).

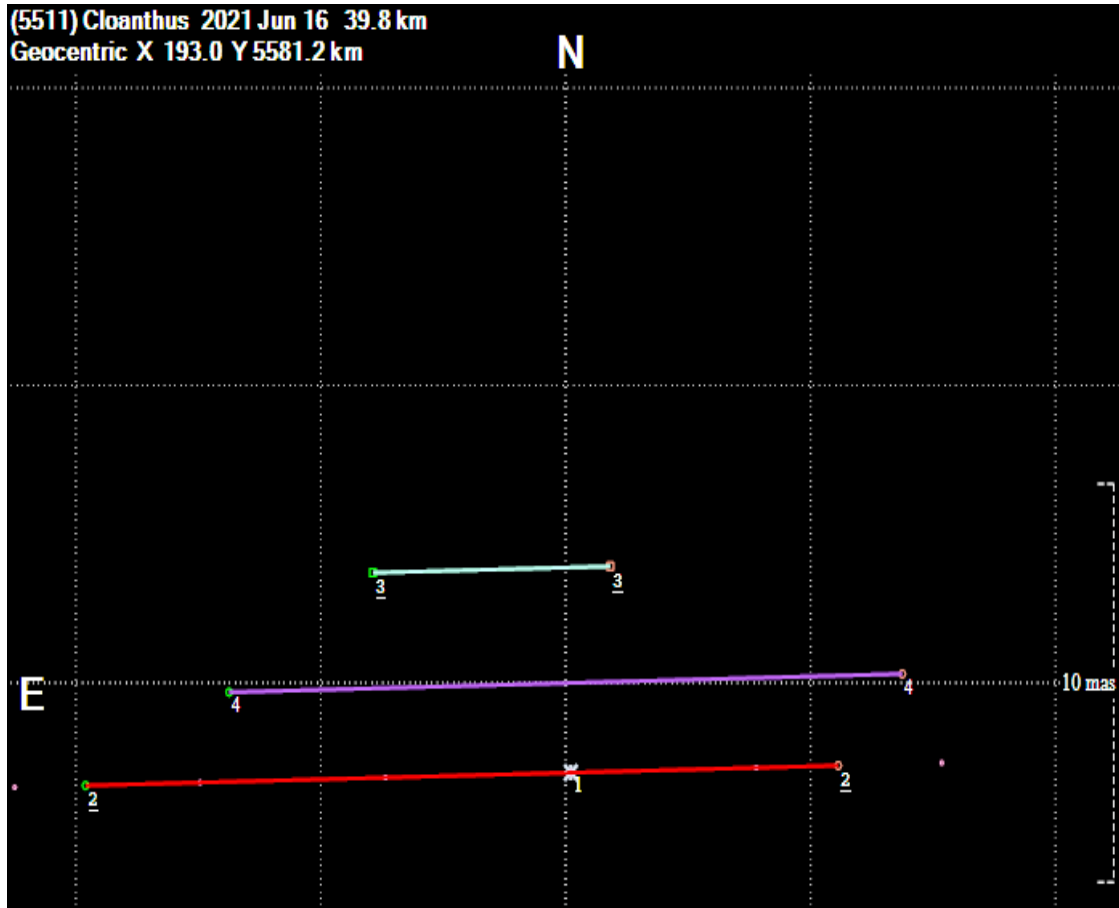


Figure 1.8. Occult4 plot of the example above: Green: single point observation (Weber, C.), red is another zero-weighted chord (Edens, E.), the purple chord is from Marciniak, A. Numbers of zero-weighted chords are underlined.

In general, observations that can be classified as uncertain should be treated with extreme caution. They require very in-depth analysis and possibly discussion in the reviewer collectives. In addition, chords from other observers are required for assessment. Especially this is true for single point events. In case of doubt it is always better not to add a problematic observation to the Occult4 database but to delete it as unreliable.

- **Unreliable**

Unreliable (inconclusive), also unknown to SODIS, are all observations which, for various reasons, do not allow a clear decision to be made as to whether or not has been an occultation event recorded (and are also not classified to be *uncertain* by the reviewers).

An example would be a predicted drop that is smaller than the noise of the recording, for a demonstration see [Figure 1.9](#).

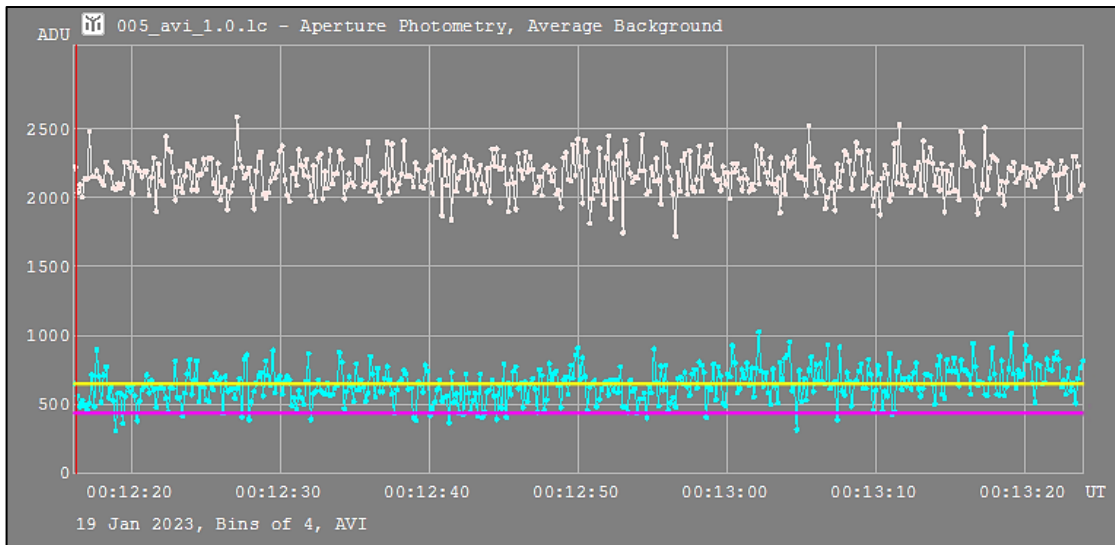


Figure 1.9. Unreliable recording example: Due to noise a drop to the predicted purple line cannot be concluded (but also not excluded).

In such situations the observer should report **"No Observation"** to OccultWatcher and *not* send a report to SODIS or delete/request deletion of a possibly already existing SODIS report.

In all doubtful cases the open questions should be discussed in the local reviewer team and/or in the SODIS observer subforum. It often helps to repeat the data reduction with different programs and parameters to clarify the situation. If all else fails, there are also professional astronomers in the occultation community.

1.3 Description of data required by SODIS

The SODIS input mask ([Figure 1.10](#)) is accessible under REPORT (<https://sodis.iota-es.de/observe/>) on the SODIS website.

Figure 1.10. SODIS input mask.

In the following, the data fields are explained and input examples are given for both an event detection (positive), [Figure 1.11](#), and a non detection (negative), [Figure 1.20](#), observation. Explanations are shown in purple or black, input examples in blue. The examples in blue show the exact spellings, note e.g. blanks. For example, for UCAC4 stars, only *one* space is allowed after UCAC4. The dot is always used as the decimal separator, all times must be entered in UTC, do not append units of measurement to values. Exact entries in the SODIS mask are essential, as the mask is read automatically (parsed) by the SODIS system. Input errors lead to SODIS not being able to read the data resulting in export failures.

Additional required files will be also indicated and it is shown how to obtain them.

Event detection (positive observation)

Choose a locally saved file
Reading in the file

Read Form
Choose File No file chosen
READ

20230228_115128_UCAC4_423_058172.txt

Choose neg/pos UTC date of observation UTC predicted date and time of the event (not the time when the prediction was made)

Occultation	Positive	Date	dd/mm/yyyy	Predictdate	dd/mm/yyyy	Predicttime	--:--:--
			04/02/2023		04/02/2023		01:33:47

First name and surname (no affiliation or similar) of a second observer (the first observer must not be entered, it is automatically written) Tick if three or more observers

Observer 2	<input type="text"/>	<input type="checkbox"/> More Obs
	Paul Miller	<input checked="" type="checkbox"/>

Name of the star (as in prediction)	Name of the body	Number
Star	Asteroid	No
UCAC4 654-041770	Catriona	1116
TYC 1393-00914-1	1999 TM256	86267
G060056.0+333720 (Gaia)	P/2022 L3	0 (0 or - if comet)
HIP 70501	Titania	P7M03 (moon)

The next village (not a city 100 km away) Choose country code of observation

Located near	<input type="text"/>	Country Code	CH
	Gnosca		

Latitude +/-DD MM SS.s				Longitude +/-DDD MM SS.s					
Latitude	DEG	M	SS	s	Longitude	DEG	M	SS	s
	50	40	31	3		-103	40	5	1
	+50	44	1	3		+103	40	05	9
	-55	40	31	0		-3	40	55	1
	00	40	31	3		003	40	5	0

Altitude, referenced to mean sea level [m] Choose type of datum

Altitude	<input type="text"/>	m	Datum Type	WGS84
	563			

Choose telescope Aperture [cm] Effective FL [cm]

Telescope	Unstated	Aperture	<input type="text"/>	cm	Focal Length	<input type="text"/>	cm
			20			89	

Choose obs. method Exposure time [s]

Obs Method	Analogue & digital video	Exp Time	<input type="text"/>	s.ss
			0.20	

("Sequential images" if FITS)

Recording start (UTC) Recording end (UTC)

Start Obs	HH	MM	SS	ms	End Obs	HH	MM	SS	ms
	22	05	20	5		22	10	30	2

Disappearance: choose type		D Time (UTC)				Accuracy D time [s]		
D	Main Star	D Time	HH	MM	SS	ms	Acc_D	s.ss
			22	07	30	12		0.08

Occultation duration [s]

Duration s

20.26

Reappearance: choose type		R Time (UTC)				Accuracy R time [s]		
R	Main Star	R Time	HH	MM	SS	ms	Acc_R	s.ss
			22	07	50	38		0.16

Time source: choose type		Type of camera		Signal to noise ratio	
Time Source	GPS	Camera			Signal/Noise
			QH174GPS		4.8

Wind [Bft]	Temperature [°C]	Choose atm. transparency	Choose seeing
Wind	Temp	Transparency	Seeing
0 (Not "no" in case of no wind)	-5	Clear	Slight flickering

Select necessary additional files (see text)

Drag & Drop your files or Browse

Observer's comment (*only the most necessary*)

Comment Powered by P2DNA

"QH174GPS lost of GPS lock just prior, but continued under partial data."
 "Uncertain. Single frame event."

Transmit the report	Discard the report (restart entries)
NEW ENTRY	DISMISS

Figure 1.11. SODIS input mask for an event detection (positive) observation. Explanations in purple or black, input examples in blue.

Grey bordered input fields in the report mask are optional. However, it is strongly recommended to fill in optional fields as well, as the additional data will facilitate the work of the reviewers.

To support the reviewers, during data entry observers are asked to submit additional data (*"Drag & Drop your files or Browse"*) as shown in [Figure 1.12](#). In the case of an event detection (positive), the respective complete data set must be submitted. [Figure 1.12](#) also shows how to get the different files. The embedded pictures in [Figure 1.12](#) give examples of what the inputs should look like.

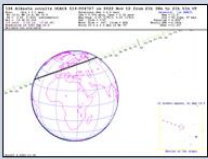
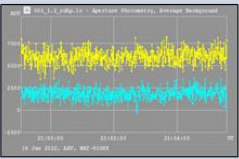
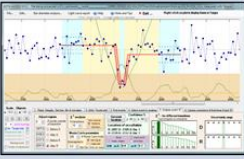

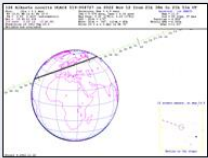
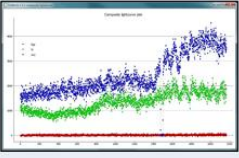
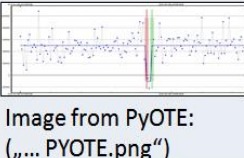
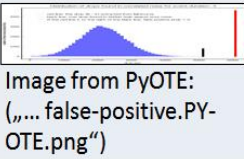

Pipeline	Event	Overview	Reduction	Log
Tangra, AOTA	 PNG-Image from Occult-Watcher: „Open Event in Occult“	 PNG-Image from Tangra: „Export lc / Save as Image File“	 PNG-Image from AOTA: „tab 5“	 Textfile („... AOTA_Report.txt“) from AOTA „tab 6“: „Save Report“
Py-Movie, PyOTE	 PNG-Image from Occult-Watcher: „Open Event in Occult“	 PNG-Image from PyMovie: „Plot“ („Composite Lightcurve Plot“)	 Image from PyOTE: („... PYOTE.png“)  Image from PyOTE: („... false-positive.PY-OTE.png“)	 Textf. („... PYOTE.log“) from PyOTE
Other (SORA, Li-movie, ...)	Please provide similar information as described above.			

Figure 1.12. Data reduction pipeline depending observer required additional submissions (case of event detection - positive observation).

- “Event” image

This image informs the reviewer of all the data of the occultation event and frees him from searching for these essential things. The image is generated by Occult4, but called from Occult Watcher with a right click on the event line (Figure 1.13).

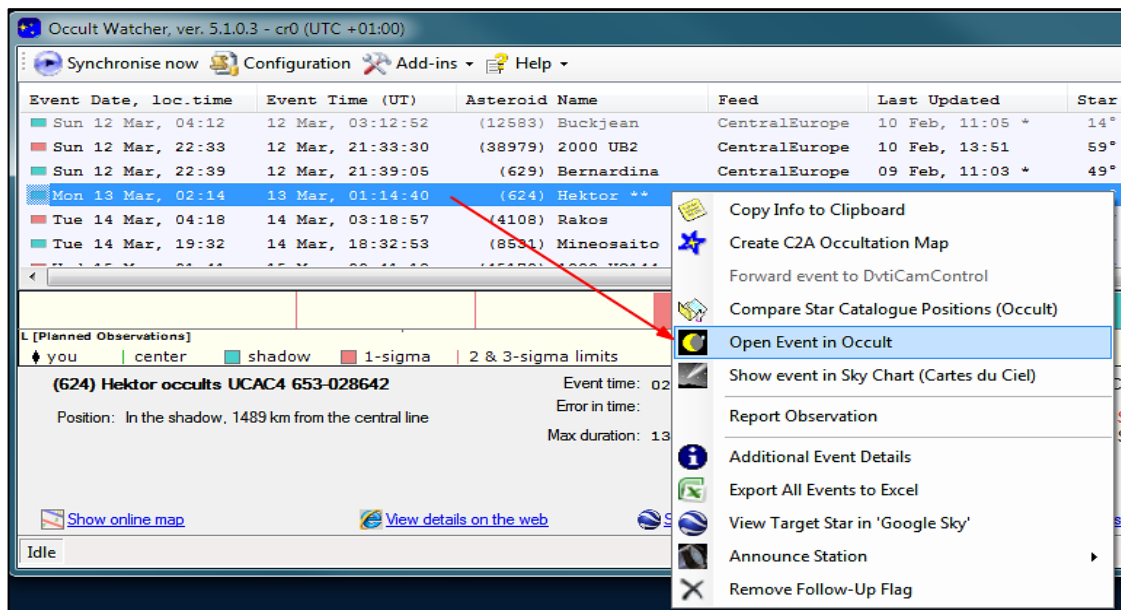


Figure 1.13. Getting the Occult image with Occult Watcher.

To obtain the image, the OW add-in “Occult Tools for OccultWatcher” is required. (Get the DLL: <http://www.hristopavlov.net/OccultWatcher/OccultWatcher.OccultTools.zip>, copy it to

the OW folder - start OW, update OW as requested). Also, the add-in must know the path to Occult4: *Configure add-ins*, choose “Occult Tools for OccultWatcher”, set up the path to Occult4 (Figure 1.14).

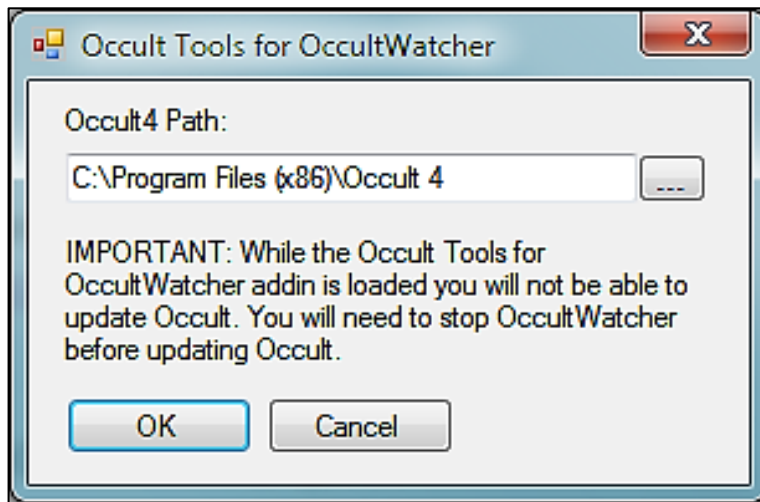


Figure 1.14. “Occult Tools for OccultWatcher” add-in: setting up the path to Occult4 (example).

If Occult4 is not installed, the observer can get the image also via Occult Watcher Cloud (OWC) (<https://cloud.occultwatcher.net/>): On the first page of the event, click “Show OccultMap” at the very bottom.

The resolution of the submitted Occult image (PNG format) must be sufficient to make all text information legible.

- **“Overview” image**

The “Overview” image should show the entire recording (or at least a large part of it), including the light curve of at least one comparison star. The image should illustrate that the detected event is truly unique - apart from multiple detections - (and does not appear repeatedly in the target light curve or in the light curve of a comparison star due to noise, for example). Furthermore, the reference light curve should not completely or partially obscure the target light curve. For better clarity, with Tangra the y-axis should show ADU and not stellar magnitudes.

- **“Reduction” image**

The “Reduction” image should have a higher temporal resolution than the “Overview” one and give a very clear indication of the extraction of the D and R times. For AOTA, a “tab5” image is mandatory because of its statistics (*not* “tab6”, whose results are included in the AOTA report, which is also mandatory). Note that when using PyOTE, the “False-Positive”-test image must also be submitted.

- **“Log” files**

These are TXT files generated by the data reduction pipelines used. In case of AOTA the report (“...AOTA_Report.txt”) is generated from tab6 using the button “Save report”. The file will be saved to the current AOTA working directory. Similar does PyOTE, the file (“...PYOTE.log”) is saved automatically during data reduction.

As can be seen in [Figure 1.12](#), for reasons of image quality, all images must be uploaded in PNG format, not JPG format.

Figures 1.15 and 1.16 show examples of insufficient or wrong uploads for positive observations.

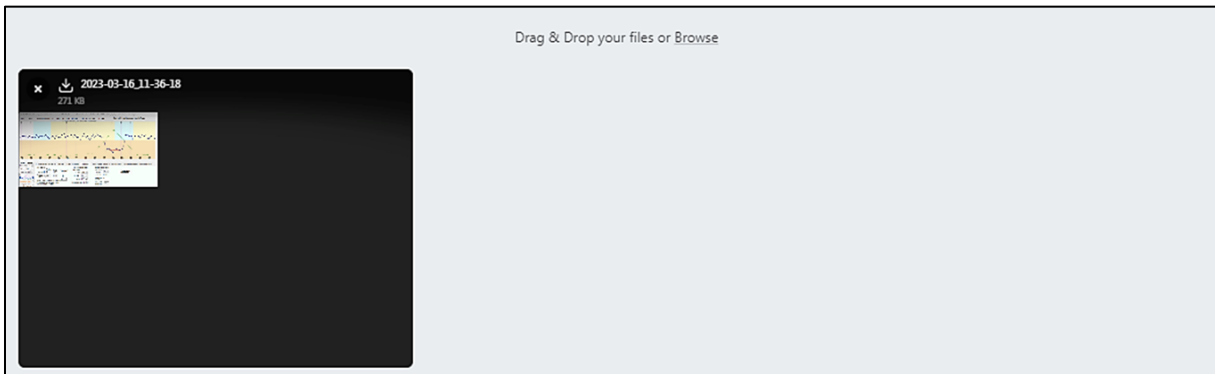


Figure 1.15. Event detection observation: only one of four required uploads (compare Figure 1.11).

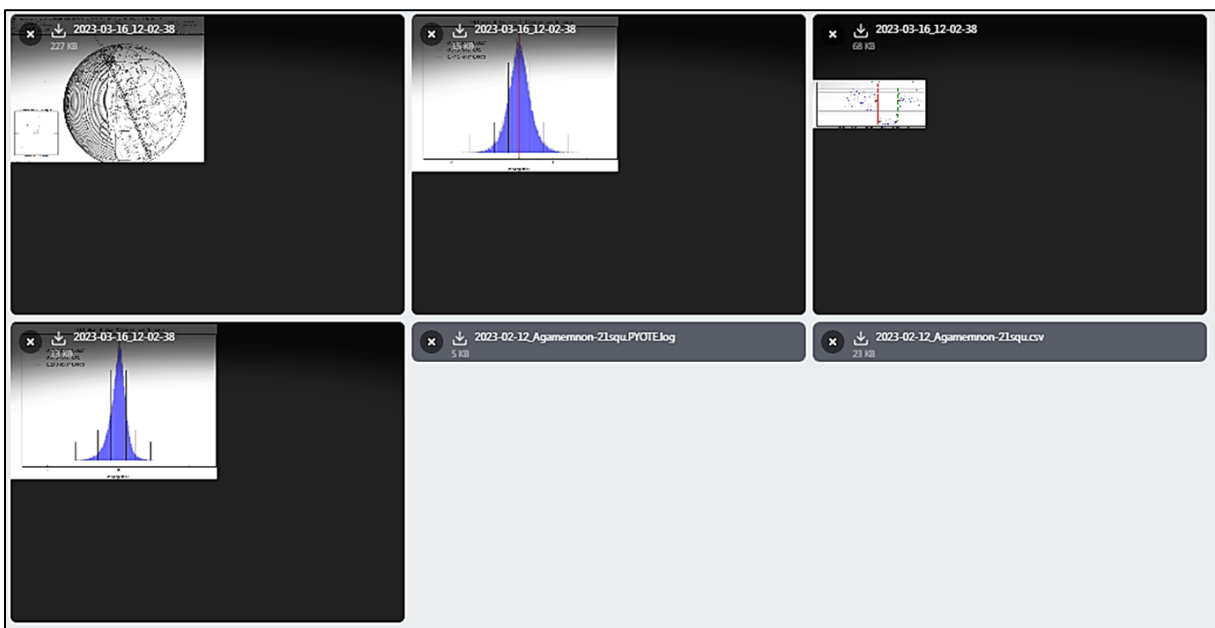


Figure 1.16. PyOTE event detection report: Missing overview- and false-positive test images, the provided two histograms are not required and redundant, (compare Figure 1.12).

If the report mask is filled in and also all the requested additional files are selected the button UPDATE ENTRY at the bottom of the entry mask must be pressed. In case of missing entries or other problems, SODIS may display corresponding error messages, see examples in Figures 1.17 and 1.18.

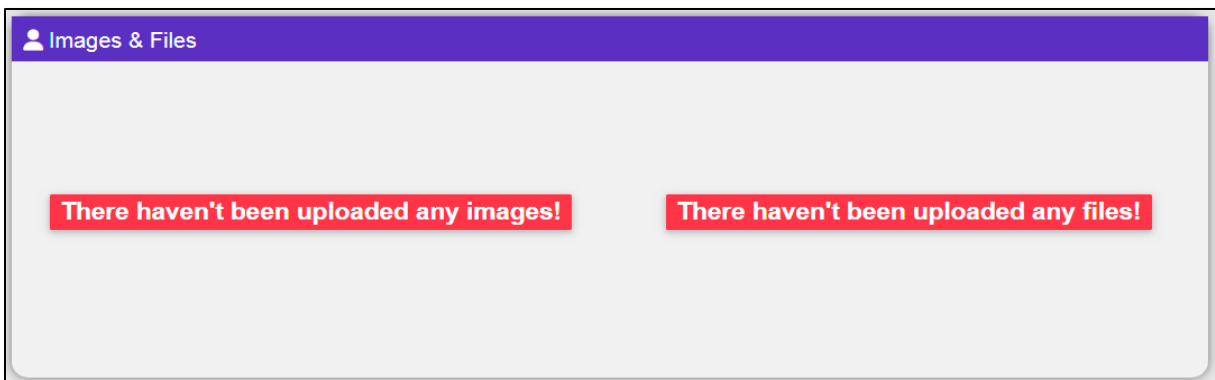


Figure 1.17. SODIS note if no additional files have been selected.

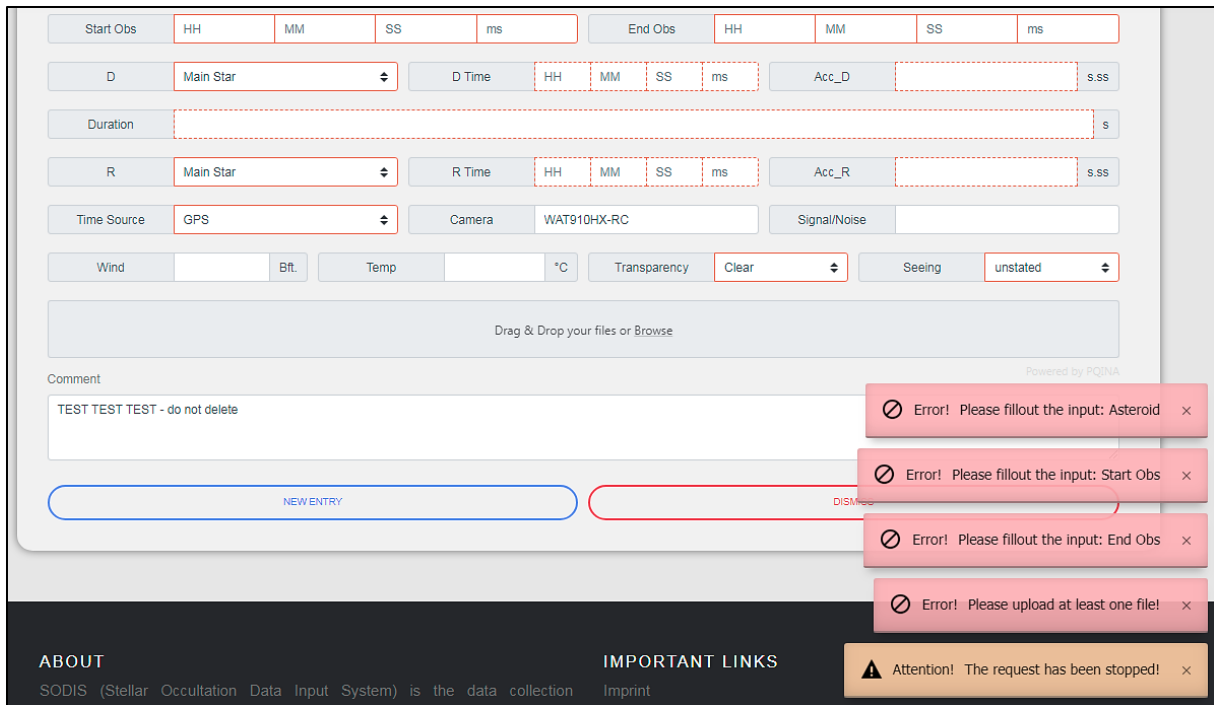


Figure 1.18. SODIS error messages in the case of entry issues.

After solving the announced issues and pressing UPDATE ENTRY the observation will be accepted by SODIS. The observer will then see a message according to [Figure 1.19](#).

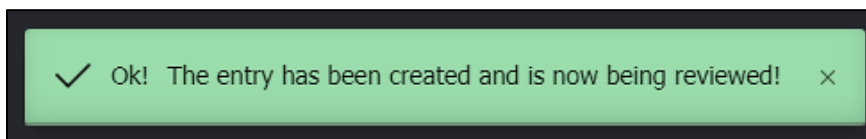


Figure 1.19. SODIS message after accepting user input.

Even after that, some tasks may remain for the observer. An overview of these tasks can be found in [Chapter 1.6](#).

The following describes how to report a non detection (negative) observation, including the additional data to be submitted. Grey bordered input fields in the report mask are optional. However, it is strongly recommended to fill in optional fields as well, as the additional data will facilitate the work of the reviewers.

Non detection (negative) observation

Choose a locally saved file
Reading in the file

Read Form Choose File No file chosen READ

20230228_115128_UCAC4_423_058172.txt

Choose neg/pos
UTC date of observation
UTC predicted date and time of the event (not the time when the prediction was made)

Occultation Negative Date dd/mm/yyyy Predictdate dd/mm/yyyy Predicttime --:--:--

04/02/2023
04/02/2023
01:33:47

First name and surname (no affiliation or similar) of a second observer (the first observer must not be entered, it is automatically written)
Tick if three or more observers

Observer 2 More Obs

Paul Miller
✓

Name of the star (as in prediction)
Name of the body
Number

Star Asteroid No

UCAC4 654-041770	Catriona	1116
TYC 1393-00914-1	1999 TM256	86267
G060056.0+333720 (Gaia)	P/2022 L3	0 (0 or - if comet)
HIP 70501	Titania	P7M03 (moon)

The next village (not a city 100 km away)
Choose country code of observation

Located near Country Code

Gnosca

Latitude +/-DD MM SS.s
Longitude +/-DDD MM SS.s

Latitude				Longitude			
DEG	M	SS	s	DEG	M	SS	s
50	40	31	3	-103	40	5	1
+50	44	1	3	+103	40	05	9
-55	40	31	0	-3	40	55	1
00	40	31	3	003	40	5	0

Altitude, referenced to mean sea level [m]
Choose type of datum

Altitude m Datum Type

563

Choose telescope
Aperture [cm]
Effective FL [cm]

Telescope Aperture cm Focal Length cm

20
89

Choose obs. method Exposure time [s]

Obs Method	Analogue & digital video	Exp Time	s.ss
------------	--------------------------	----------	------

("Sequential images" if FITS) 0.20

Recording start (UTC) Recording end (UTC)

Start Obs	HH	MM	SS	ms	End Obs	HH	MM	SS	ms
	22	05	20	5		22	10	30	2

Disappearance: choose type D Time (UTC) Accuracy D time [s]

D	Non Detection	D Time	HH	MM	SS	ms	Acc_D	s.ss
---	---------------	--------	----	----	----	----	-------	------

(In the case of non detection: all fields are locked and remain empty)

Occultation duration [s]

Duration		s
----------	--	---

(In the case of non detection: field is locked and remains empty)

Reappearance: choose type R Time (UTC) Accuracy R time [s]

R	Non Detection	R Time	HH	MM	SS	ms	Acc_R	s.ss
---	---------------	--------	----	----	----	----	-------	------

(In the case of non detection: all fields are locked and remain empty)

Time source: choose type Type of camera Signal to noise ratio

Time Source	GPS	Camera		Signal/Noise	
-------------	-----	--------	--	--------------	--

QHY174GPS 4.8

Wind [Bft] Temperature [°C] Choose atm. transparency Choose seeing

Wind	0	Bft.	Temp	-5	°C	Transparency	Clear	Seeing	Slight flickering
------	---	------	------	----	----	--------------	-------	--------	-------------------

0 (Not "no" in case of no wind) -5

Select necessary additional files (see text)

Drag & Drop your files or [Browse](#)

Observer's comment *(only the most necessary)*

Comment Powered by PJQINA

Transmit the report Discard the report (restart entries)

NEW ENTRY	DISMISS
-----------	---------

Figure 1.20. SODIS input mask for a non detection (negative) observation. Explanations in purple or black, input examples in blue.

Also for a non detection report, some additional, but less than for a detection, files have to be submitted ([Figure 1.21](#)). The requirements and how to obtain these files are described above under the descriptions for positive observations.

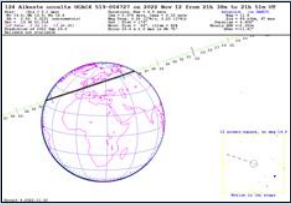
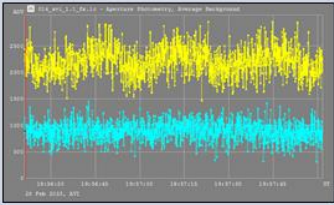
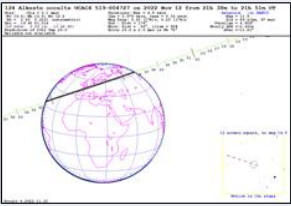
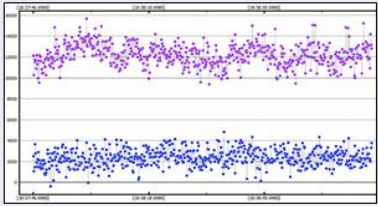
Pipeline	Event	Overview
Tangra, AOTA	 <p>PNG-Image from Occult-Watcher: „Open Event in Occult“</p>	 <p>PNG-Image from Tangra: „Export lc / Save as Image File“</p>
Py- Movie, PyOTE	 <p>PNG-Image from Occult-Watcher: „Open Event in Occult“</p>	 <p>PNG-Image from PyMovie: „Plot“ („Composite Lightcurve Plot“)</p>
Other (SORA, Li- movie, ...)	Please provide similar information as described above.	

Figure 1.21. Data reduction pipeline depending additional files to be transmitted in case of a non detection (negative) event.

As can be seen from [Figure 1.21](#), for non detection observations only the “Event” and “Overview” images are required. [Figure 1.22](#) shows an insufficient upload.

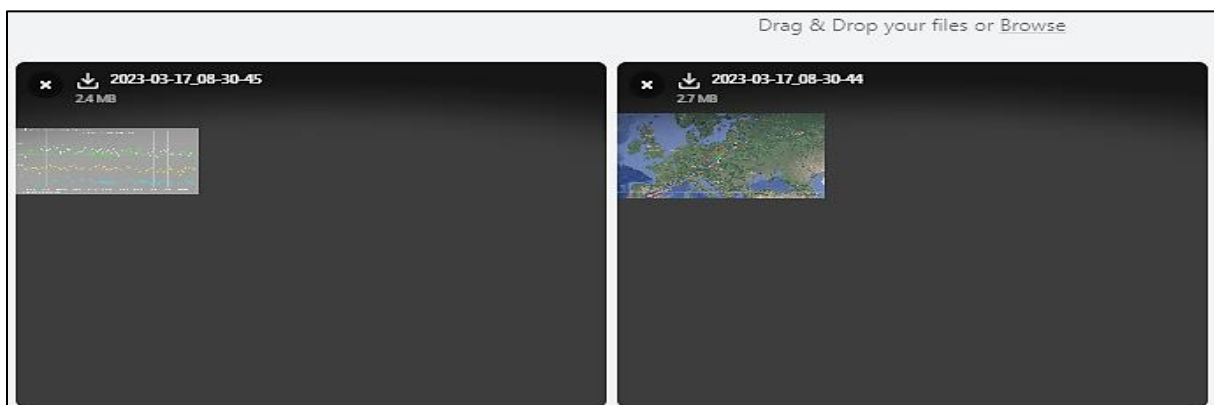


Figure 1.22. Non detection, insufficient upload: the event image is missing, the map shown is not required.

For recordings with and without detection, it is initially not necessary to upload a light curve file, nor any additional files beyond those described. If additional data is required, the reviewer will contact the observer.

Observers should be aware that the more closely they follow the reporting requirements outlined, the more they will assist the work of the reviewers, avoid queries and facilitate rapid recognition of their observation.

1.4 SODIS reporting - the best way

The method is the most appropriate as many potential problems/input failures are avoided. The approach is to *upload the pre-filled report form* into the SODIS REPORT mask (button “Choose file” at the top of [Figure 1.10](#)), followed by some manual additions and by uploading the required additional files according to [Chapter 1.3](#).

Please do not forget to also tell Occult Watcher your observation result (+, -, no observation).

The SODIS report form is a TXT file, similar to the old Planoccult message system and basing on the Occult4 XML observation format requirements. The report form can be downloaded from <https://forum.iota-es.de/showthread.php?tid=1>. As the report form is updated from time to time, observers should always use the latest version. The current version is “IOTA-ES_report_203.txt” and is plotted in the appendix, [Chapter 5.2](#).

There are two ways to pre-fill the report form.

- **Using the Report add-in of Occult Watcher**

With this recommended method essential data fields are automatically written by Occult Watcher. The required add-in is already included in current OW installations (the corresponding dll is “OccultWatcher.Reports.dll”). [Figure 1.23](#) shows how the add-in works, [Figure 1.24](#) gives an example of an observation.

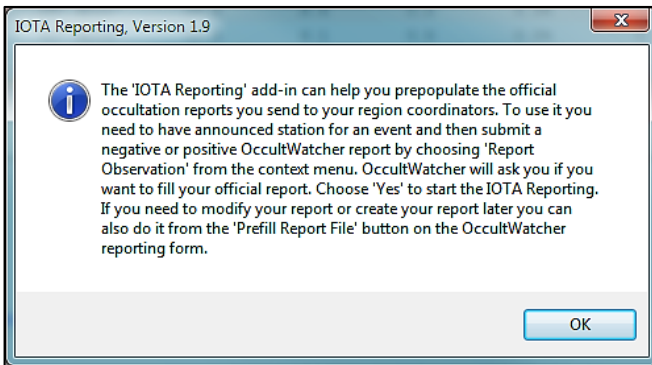


Figure 1.23. Description of the OW IOTA Reporting add-in.

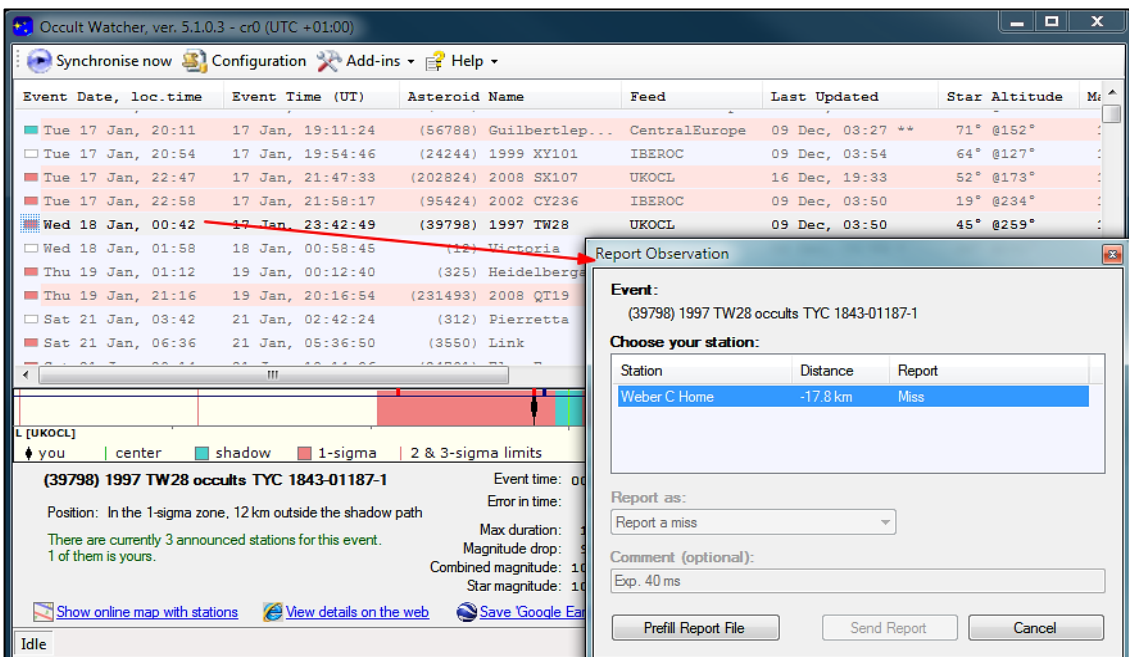


Figure 1.24. Right clicking on the event line after the observation (a station must have been announced before the event) opens the possibility “Prefill Report File”.

The SODIS report form TXT file must be copied to the "OccultWatcher\Report Templates\" directory to be found by the OW Report add-in.

By clicking "Prefill Report File" one gets firstly a warning (Figure 1.25), afterwards a window according to Figure 1.26 opens.

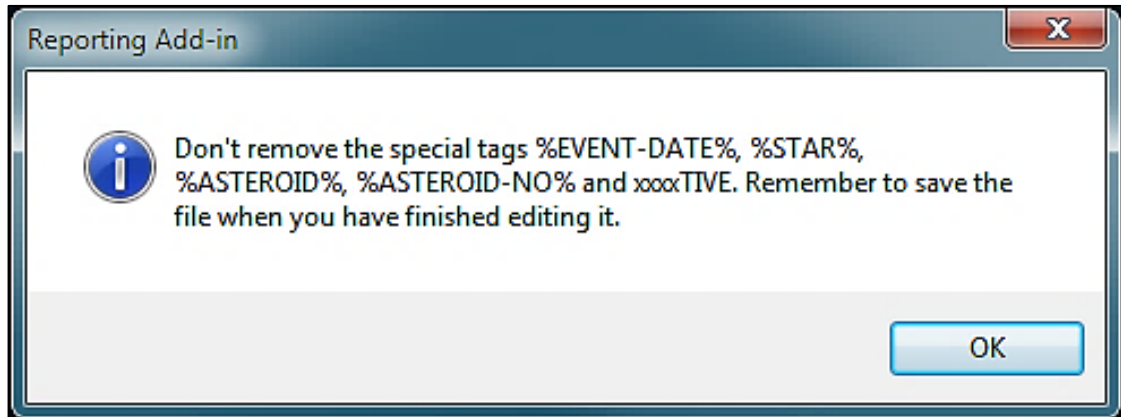


Figure 1.25. Warning after clicking "Prefill Report File".

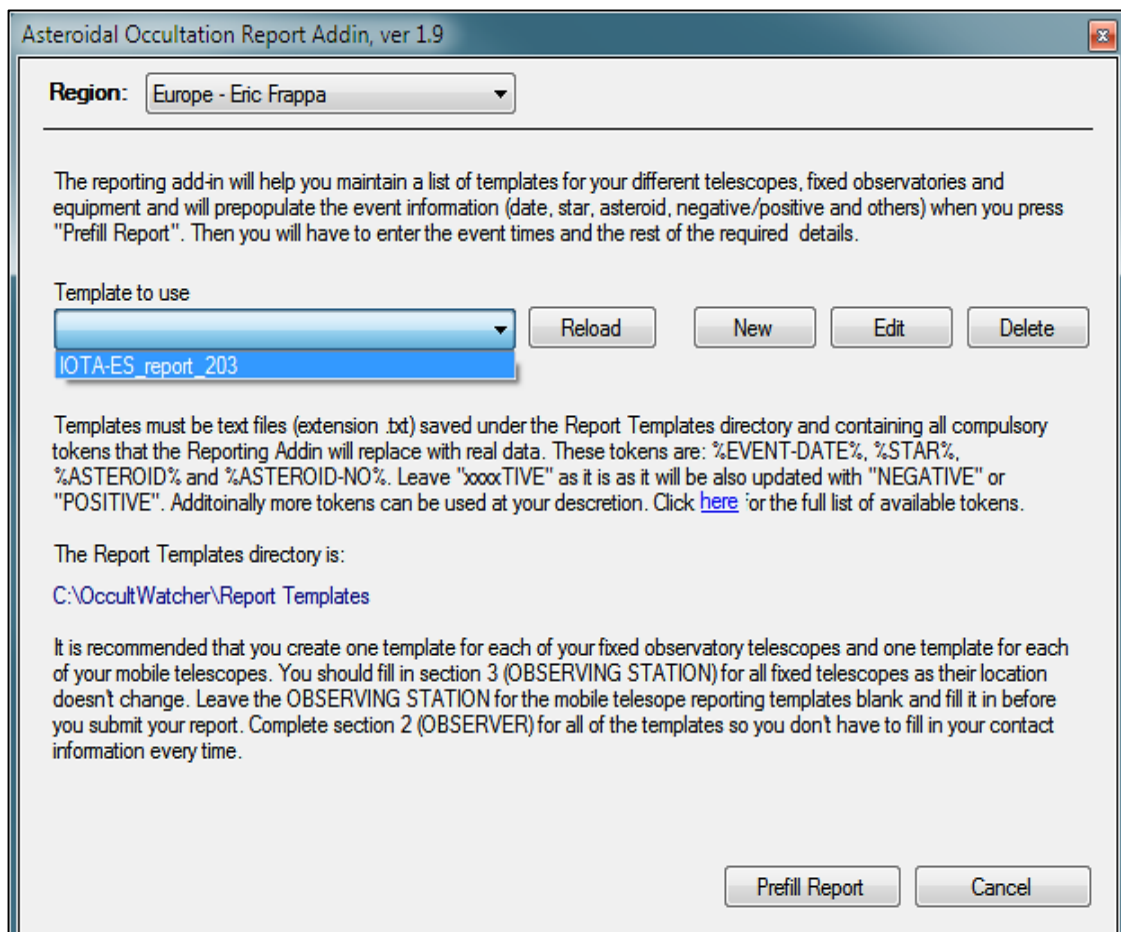


Figure 1.26. Dialogue of the OW Report Add-in (for SODIS reporting the "Region" does not play a role).

After choosing *IOTA_report_203* and clicking "Prefill Report" we get (after saving) the pre-filled report file *20230117_39798_TYC_1843_01187_1.txt*:

#IOTA-ES ASTEROIDAL OCCULTATION - REPORT FORM 2.03

#Event

#Occultation: *NEGATIVE*

#DATE: *17 January 2023*

#PREDICTTIME: *17 Jan; 23:42:49 UT*

#STAR: *TYC 1843_01187_1*

#ASTEROID: *1997 TW28*

#Nr: *39798*

#OBSERVER

#Observer1:

#Observer2:

#moreObs:

#E-mail:

#Address:

#OBSERVING_STATION

#Located near:

#Countrycode:

#Coordinates LAT +/-DD MM SS.S LON +/-DDD MM SS.S

#Latitude:

#Longitude:

#Altitude:

#Datum _blank=WGS84 N=NAD1927 E=ED1950 T=Tokyo G=GB1936 *=unspecified, or other

#Datum:

#Teleskop _=unstated 1=Reflector 2=Newtonian 3=SCT 4=Dobsonian 5=Binoculars 6=Other
7=None 8=eVscope

#Telescope:

#Aperture in cm

#Aperture:

#FocalLength in cm

#FocalLength:

#ObservingMethod _=unspecified a=Analogue & digital video b=Digital SLR-camera video
c=Photometer d=Sequential images e=Drift scan f=Visual g=Other

#ObservingMethod:

#Observation

#StartObs:

#D D=Main Star d=second Star G=satellite main star g=satellite 2nd star N=ring M=non detection
+time hh:mm:ss.s

#D:

#Acc_D:

#R R=Main Star r=second Star B=satellite main star b=satellite 2nd star N=ring M=non detection
+time hh:mm:ss.s

#R:

#Acc_R:

#EndObs:

#Duration:

#Exp_Time:

#Timesource _=unspecified a=GPS b=NTP c=Telephone (fixed or mobile) d=Radio time signal
e=Internal clock of recorder f=Stopwatch g=Other

#Timesource:

#Camera:

#Signal/Noise:

#Weatherconditions

#Wind:

#Temperature:

#Transparency 1=Clear 2=Fog 3=Thin cloud <2 [mag loss <2 mag.] 4=Thick cloud >2 [mag loss >2
mag. 5=Broken opaque cloud [that is, observed thru gaps in the cloud] 6=Star faint 7=By averted
vision

#Transparency: 3


```
#Stability_ =unstated 1=Steady 2=Slight flickering 3=Strong flickering
#Stability:
#Comments
```

It can be seen that essential entries (in dark green) are done by OW in a SODIS readable way. The file can now be used for read-in into the SODIS report mask. However, there are a lot of fields left. These fields can be manually edited, e.g. to create several templates for combinations of several telescopes, image trains, observing locations and so on. So, later after SODIS read-in, only a few fields must be filled in manually e.g. start/end of observation, D/R times and exposure duration. [Figure 1.27](#) shows an example.

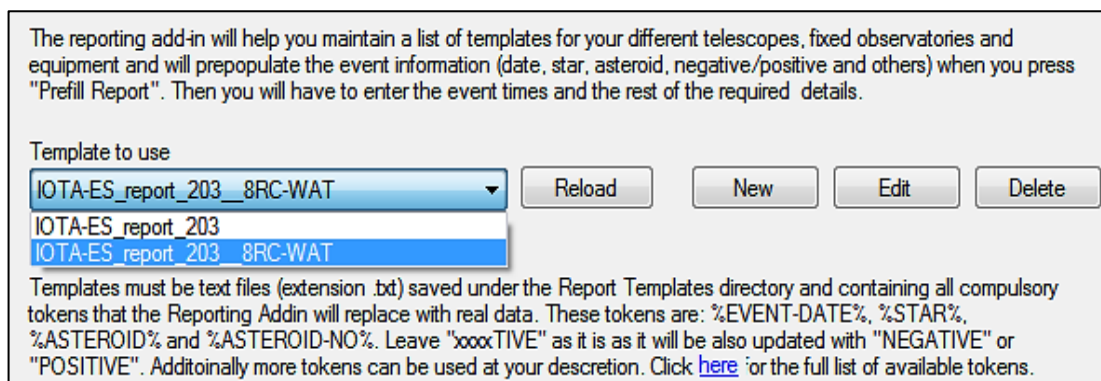


Figure 1.27. Calling up a template that has been created for a specific setup.

For the example shown in [Figure 1.27](#), the result is as follows (all the green items are filled in automatically). The red items would be left for manual entry in case of a positive observation. The orange items are optional but it is recommended to fill in them also. The use of prefilled templates largely avoids problems such as, for example, errors when entering geographical coordinates. Incorrect geographical coordinates (including altitude) are one of the most common input errors and - unfortunately - also have a major impact on the final results

```
#IOTA-ES ASTEROIDAL OCCULTATION - REPORT FORM 2.03
#Event
#Occultation: NEGATIVE
#DATE: 17 January 2023
#PREDICTTIME: 17 Jan; 23:42:49 UT
#STAR: TYC 1843_01187_1
#ASTEROID: 1997 TW28
#Nr: 39798
#OBSERVER
#Observer1: (will be automatically filled in by SODIS)
#Observer2: Frank Muller
#moreObs:
#E-mail:
#Address:
#OBSERVING_STATION
#Located near: Xtown
#Countrycode: DE
#Coordinates LAT +/-DD MM SS.S LON +/-DDD MM SS.S
#Latitude: 42 35 48.0
#Longitude: 023 35 40.4
#Altitude: 470
#Datum_blank=WGS84 N=NAD1927 E=ED1950 T=Tokyo G=GB1936 *=unspecified, or other
#Datum:
```

```

#Teleskop _=unstated 1=Refractor 2=Newtonian 3=SCT 4=Dobsonian 5=Binoculars 6=Other
7=None 8=eVscope
#Telescope: 6
#Aperture in cm
#Aperture: 21
#FocalLength in cm
#FocalLength: 90
#ObservingMethod _=unspecified a=Analogue & digital video b=Digital SLR-camera video
c=Photometer d=Sequential images e=Drift scan f=Visual g=Other
#ObservingMethod: a
#Observation
#StartObs:
#D D=Main Star d=second Star G=satellite main star g=satellite 2nd star N=ring M=non detection
+time hh:mm:ss.s
#D:
#Acc_D:
#R R=Main Star r=second Star B=satellite main star b=satellite 2nd star N=ring M=non detection
+time hh:mm:ss.s
#R:
#Acc_R:
#EndObs:
#Duration:
#Exp_Time:
#Timesource _=unspecified a=GPS b=NTP c=Telephone (fixed or mobile) d=Radio time signal
e=Internal clock of recorder f=Stopwatch g=Other
#Timesource: a
#Camera: WAT910HX-RC
#Signal/Noise:
#Weatherconditions
#Wind:
#Temperature:
#Transparency 1=Clear 2=Fog 3=Thin cloud <2 [mag loss <2 mag.] 4=Thick cloud >2 [mag loss >2
mag. 5=Broken opaque cloud [that is, observed thru gaps in the cloud] 6=Star faint 7=By averted
vision
#Transparency:
#Stability _=unstated 1=Steady 2=Slight flickering 3=Strong flickering
#Stability:
#Comments:

```

After reading in the above file into the SODIS report mask only some fields remain which must be entered manually, depending of the kind of observation ([Figure 1.28](#)).

The screenshot shows a SODIS report form with the following data and color-coding:

- Read Form:** Choose File 20230117_39798_TYC_1843_01187_1_8RC-WAT.txt READ
- Occultation:** Negative | Date: 17/01/2023 | Predictdate: 17/01/2023 | Predicttime: 23:42:49
- Observer 2:** Frank Muller
- Star:** TYC 1843-01187-1 | Asteroid: 1997 TW28 | No: 39798
- Located near:** Xtown | Country Code: DE
- Latitude:** 42 35 48 0 | **Longitude:** 023 35 40 4
- Altitude:** 470 m | Datum Type: WGS84
- Telescope:** Other | Aperture: 21 cm | Focal Length: 90 cm
- Obs Method:** Analogue & digital video | **Exp Time:** s.ss
- Start Obs:** HH MM SS ms | **End Obs:** HH MM SS ms
- D:** Non Detection | D Time: HH MM SS ms | Acc_D: s.ss
- Duration:** s
- R:** Non Detection | R Time: HH MM SS ms | Acc_R: s.ss
- Time Source:** GPS | Camera: WAT910HX-RC | Signal/Noise
- Wind:** Bft. | Temp: °C | **Transparency:** Clear | **Seeing:** unstated

Figure 1.28. SODIS reading of the specially prepared report form described above. (blue: file to read, dark green: filled in by OW, light green: manually edited, red and orange: to be manually fill in in case of a positive observation (orange fields are optional but recommended)).

- **Manually edit/fill in the report form**

Although the above method with Occult Watcher is highly recommended, in cases without Occult Watcher or for other reasons, the IOTA/ES report form can of course be fully edited manually at any time.

1.5 SODIS reporting - other ways

In addition to using the SODIS reporting form, there are a few other options.

- **Fully manual data entry directly on the SODIS website**

Observers who do not wish to use the report form can enter all data manually directly on the SODIS REPORT page. However, the risk of incorrect entries and problems is greater than when using the report template. Even with manual data entry, the additional files ([Chapter 1.3](#)) have to be uploaded.

- **If nothing helps ...**

Observers who do not want to register with SODIS can ask an already registered person to *report on their behalf*. In this case, the registered user must create a SODIS account under the name of the non-registered observer but with his own e-mail address. The observer's own SODIS account is not affected by this.

All observers can also contact the SODIS team directly via e-mail under sodis@iota-es.de.

1.6 After reporting

If an observer has sent a report to SODIS, it is saved in the system and shown on the REVIEW page (only available for reviewers). The reviewers automatically receive an e-mail about the new observation.

The observation is also displayed in the observer's personal area, which is accessible to the observer when he clicks on his avatar ([Figure 1.29](#)).

Date	Predicttime	AstNo	AstName	Occ	Duration	CC	Observer	ObsMeth	Review Status
2023-01-17	2023-01-17, 23:42:49	39798	1997 TW28	O-		DE	Christian Weber, Frank Muller	Analogue & digital video	Waiting for review
2023-02-28	2023-02-28, 22:38:06	115128	2003 SC51	O-		DE	Christian Weber	Analogue & digital video	Finished

Figure 1.29. Example of an observer's personal area, accessible via the avatar. The first row shows a newly submitted observation that has an EDIT button. The second observation shown is closed and can no longer be edited or deleted (but an administrator can delete it).

As long as no review has been made, the observer can still edit and delete his observation ([Figures 1.30](#) and [1.31](#)).

All times are entered in UTC.

Occultation: Negative | Date: 17/01/2023 | Predictdate: 17/01/2023 | Predicttime: 23:42:49

Observer 2: Frank Muller | More Obs

Star: TYC 1843-01187-1 | Asteroid: 1997 TW28 | No: 39798

Figure 1.30. Top of the editable observation from [Figure 1.29](#).

UPDATE ENTRY | DELETE

Map

Map showing geographical position with a red dot indicating the location near Elin Pelin and Novi Han.

Figure 1.31. Bottom of the editable observation from [Figure 1.29](#). Note especially the zoomable map with a red dot indicating the geographical position - a recommended possibility to check if the position was entered correctly. At the top the buttons to confirm possible edits or to delete the observation.

If an observer has sent a report to SODIS and everything seems to be in order, he may not be out of the game yet, as he should expect possible queries from a reviewer. About such a query the observer will be informed by an automatic e-mail from SODIS (verification required, see [Figure 1.3](#)). Again

under the avatar, the observer will find the observation now marked with a red x “Waiting on change” (Figure 1.32).

Date	Predicttime	AstNo	AstName	Occ	Duration	CC	Observer	ObsMeth	Review Status	
2023-01-17	2023-01-17, 23:42:49	39798	1997 TW28	O-		DE	Christian Weber, Frank Muller	Analogue & digital video	✗ Waiting on change	EDIT
2023-02-28	2023-02-28, 22:38:06	115128	2003 SC51	O-		DE	Christian Weber	Analogue & digital video	✓ Finished	VIEW

Figure 1.32. “Waiting on change” indication of the first row observation.

When the observer opens such a "Waiting on change" report, he sees the claims of the reviewer (Figure 1.33).

Figure 1.33. Example of a reviewer request.

If the observer has fulfilled the reviewer’s request he presses UPDATE ENTRY (Figure 1.34) and a new review can start.

Figure 1.34. UPDATE ENTRY to confirm changes on reviewer’s request, DELETE to remove the observation from SODIS.

2 Behind the scenes of SODIS: Review and data export

It can also be interesting for observers to take a look behind the scenes of SODIS. The following section gives an overview of the review process and the export of the data.

2.1 What happens after a new observation entry?

After a new SODIS observation entry, reviewers receive an automatically generated e-mail (e-mail verification required under the personal avatar) containing the country code ([Figure 2.1](#)). The link in the e-mail takes the reviewer directly to the relevant SODIS REVIEW page.



Figure 2.1. SODIS e-mail to the reviewers.

2.2 Who carries out the review?

Depending on the country the observation originates from, currently the following regional responsibilities (reviewer teams) exist ([Figure 2.2](#)).

The review areas and the names of the reviewers are:

Team	Chief reviewer	Deputy reviewer	Reviewer
BE			Olivier Schreurs (BE), Roland Boninsegna (BE)
CH	Jonas Schenker (CH)	Stefan Meister (CH)	
CZ+SK	Jan Manek (CZ)	Jiri Polak (CZ)	Karel Halir (CZ)
DE+AT+NL	Wolfgang Beisker (DE)	Gregor Krannich (DE)	
ES+PT	Carlos Perello (ES)	Ricard Casas (ES)	Carles Schnabel (ES)
FR	Thierry Midavaine (FR)	Arnoud Leroy (FR)	Pierre le Cam (FR), Matthieu Conjat (FR)
GB+IE	Tim Haymes (GB)	Alex Pratt (GB)	Simon Kidd (GB), William Stewart (GB)
IT	Stefano Sposetti (CH)	Claudio Costa (IT)	
PL	Wojciech Burzynski (PL)	Daniel Blazewicz (PL)	

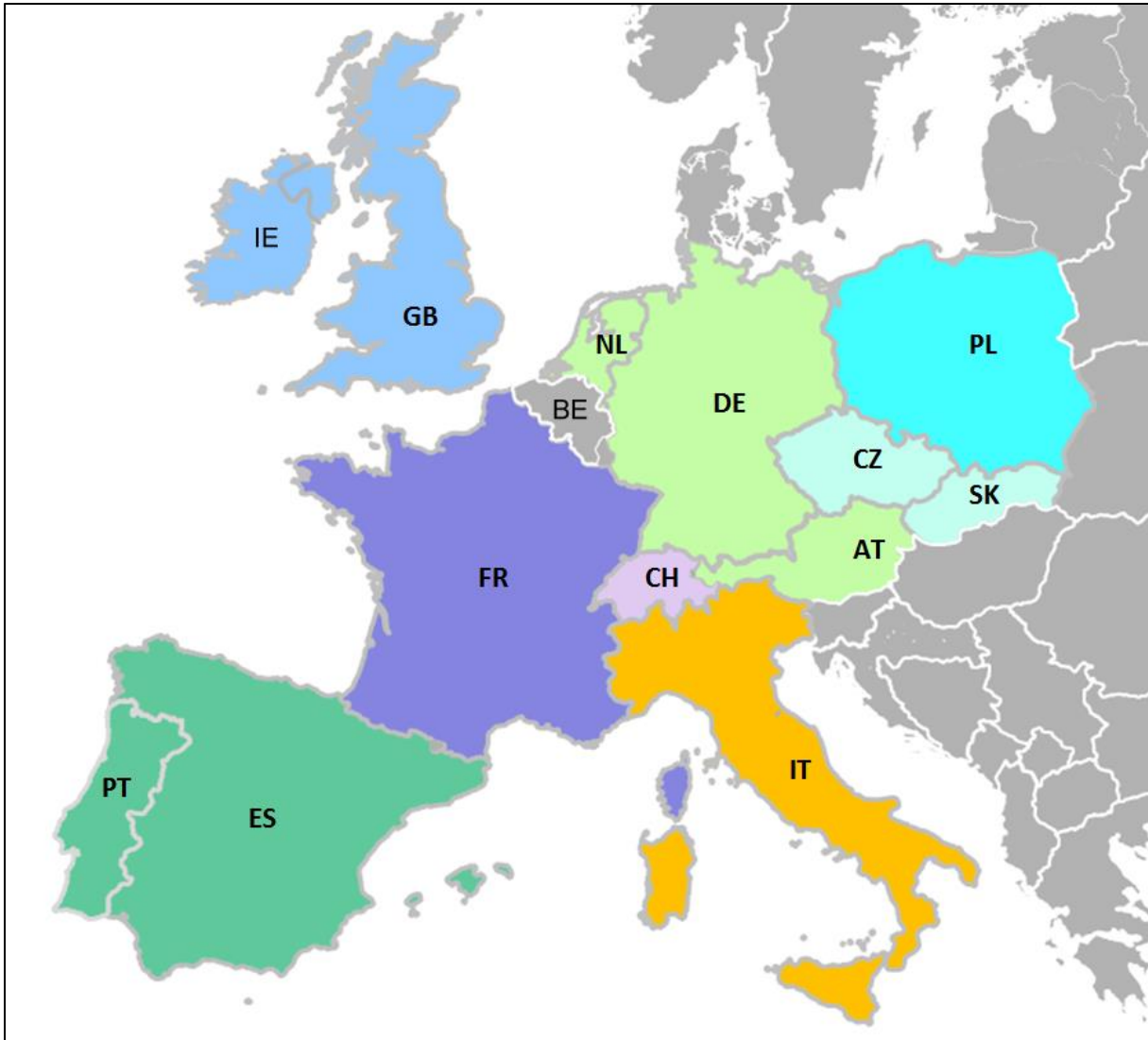


Figure 2.2. Country responsibilities of the reviewer teams (Template source: <https://graphic-flash-sources.com/free-editable-powerpoint-map-of-europe/>).

According to ISO 3166, the two-digit European Country Codes (CC) are as follows. Source: <https://www.destatis.de/Europa/EN/Country/Country-Codes.html>

Albania	AL
Andorra	AD
Austria	AT
Belarus	BY
Belgium	BE
Bosnia and Herzegovina	BA
Bulgaria	BG
Croatia	HR
Cyprus	CY
Czechia	CZ
Denmark	DK
Estonia	EE
Finland	FI
France	FR

Germany	DE
Greece	GR
Hungary	HU
Iceland	IS
Ireland	IE
Italy	IT
Latvia	LV
Liechtenstein	LI
Lithuania	LT
Luxembourg	LU
Malta	MT
Moldova, Republic of	MD
Monaco	MC
Montenegro	ME
Netherlands	NL
North Macedonia	MK
Norway	NO
Poland	PL
Portugal	PT
Romania	RO
San Marino	SM
Serbia	RS
Slovakia	SK
Slovenia	SI
Spain	ES
Sweden	SE
Switzerland	CH
Russian Federation	RU
Turkey	TR
Ukraine	UA
United Kingdom	GB
Vatican City	VA

Observations from countries that do not belong to a region are handled by the SODIS administration. The administration can ask the neighboring region to take care of it.

Who performs the review within a local review team is a matter for the review team. It is obvious that reviewers should not review their own observations. In such cases, they should ask a reviewer from the neighbouring region or another reviewer from their own team.

For observations from another country, the country code of the country where the observation took place must be given (Occult4 requirement). When such an observation is received, the reviewer passes it on to the reviewer team of the observer's country of origin.

2.3 What does the reviewer do on the review page?

[Figure 2.3](#) shows schematically an example from the REVIEW page that the reviewer has to deal with. There are a number of input fields that the observer fills in when making entries, and also some additional data at the bottom of the page. The "Comment" field may also contain some remarks by the observer.

The screenshot displays the 'Review Entry' interface for a non-detection observation. The top section is a form with various input fields for observation details, including 'Observer', 'Date', 'Position', 'Observer 2', 'Site', 'Location', 'Latitude', 'Longitude', 'Altitude', 'Observer', 'Observer 2', 'Time Since', 'Wind', 'Temp', 'Humidity', 'Cloud', 'Seeing', and 'Dewy'. Below the form are two image thumbnails. The middle section, titled 'Images & Files', contains a technical data block, a red warning message 'There haven't been uploaded any files!', a 3D globe visualization, and a 2D map with a red circular area of interest. The bottom section is a 'Log' table with columns for 'New Comment', 'User', and 'Time'.

New Comment	User	Time
Wolfgang Belcher Comment added and imported	Wolfgang Belcher	2023-03-04 14:25:48
Wolfgang Belcher Changed the report	Wolfgang Belcher	2023-03-04 14:25:48

Figure 2.3. Observation example from the REVIEW page (schematic, non detection observation).

First, the reviewer checks whether all required input fields have been filled in correctly and all additional data has been uploaded. If all data is available, the second step for the reviewer is to familiarise with the event itself, using the "Event" image and also, if in doubt, to take his own look at

the event in Occult Watcher or Occult Watcher Cloud (OWC can also display past events), in some circumstances it may be necessary for the reviewer to perform an own Occult4 search.

The reviewer can then examine the observer's data reduction. He should also have an eye on the observations of others for the same event, e.g. to find out time errors.

The final step in a review that has gone smoothly up to this point is to assess a few more things, see [Figure 2.4](#). [Figure 2.5](#) gives details regarding D- and R-weighting. All these options should be used with caution. Usually the default settings are sufficient.

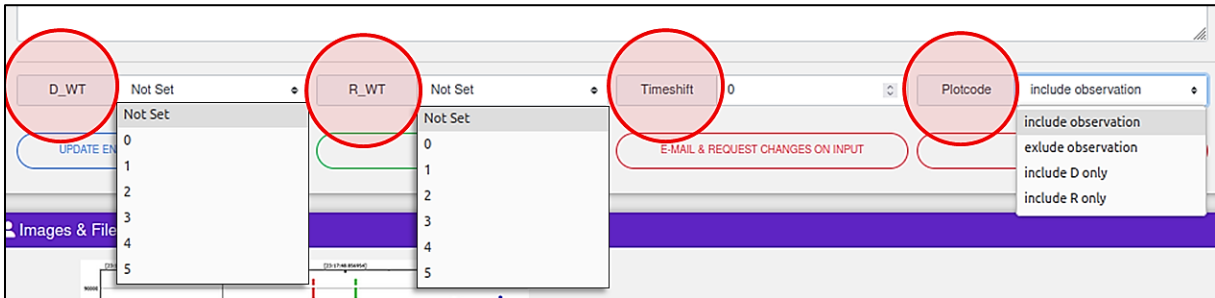


Figure 2.4. Additional assessments on the REVIEW page; “Not Set”, “Not Set”, “0” and “include observation” are the default settings, which are correct in the vast majority of cases.

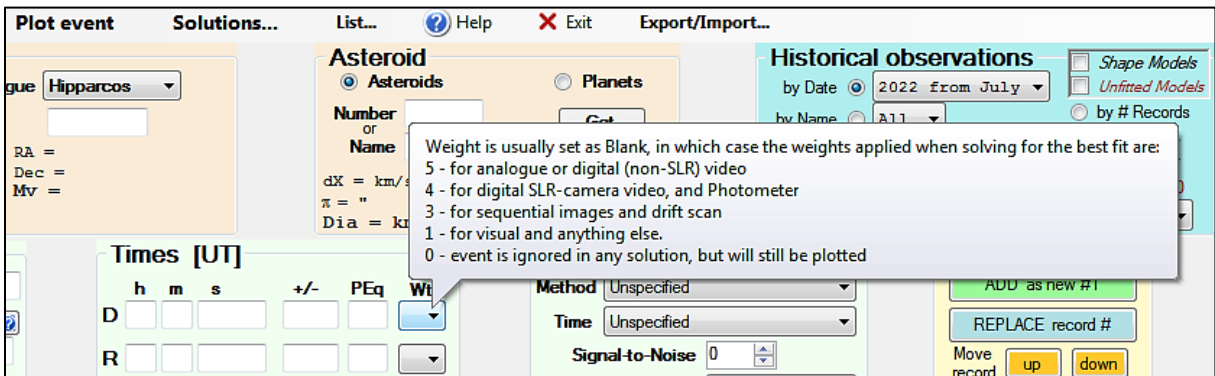


Figure 2.5. D- and R-weighting options (from Occult4/Observations editor).

The following explanations of these functions are taken from the Occult4/Observations editor help.

- D-weighting D_WT and R-weighting R_WT**
 “Wt. A value of, and 0 to 5. This field should normally be left blank - in which case visual observations are weighted as 1 and video observations are weighted as 3. However during analyses stages it may be appropriate to apply different weightings (within the range 0 to 5). A weighting of 0 results in an observation being excluded from the solution but included in the plot of observations (with the observation number being underlined).”
- Timeshift**
 “Time Shift (secs) This is an adjustment applied in analysis to bring a discordant observation into alignment with other observations. It assumes the existence of an error in the time base used by the observer. A time shift should not be applied without good reason.”
- Plotcode**
 “This field identifies observations that are excluded from the solution (including the graphic display of the event. The choices available are:

Option (Code)	Comments
Include observation ()	Both the D and R events are included in the solution, and plotted
Include D only (x)	Only the D event is included in the solution and plotted. The R event is ignored
Include R only (y)	Only the R event is included in the solution and plotted. The D event is ignored
Exclude observation (z)	The complete observation is excluded from the solution, and is not plotted

The setting can be used to: to exclude an apparently erroneous observation; or exclude extremely distant not-detected events, so that the plot of the events is properly concentrated on the observed chords and close not-detected events.”

After checking the above settings the reviewer confirms possible changes made by pressing the UPDATE ENTRY & SET REVIEWER FIELDS button ([Figure 2.6](#)).



Figure 2.6. Button to accept entries by the reviewer.

With this button the reviewer also confirms possible changes in observer entry fields. Note: With this button the review is not yet accepted by SODIS.

If doubts arise during the verification process, the reviewer can also send an e-mail to the observer asking for clarification or changes. This is done by pressing the corresponding button ([Figure 2.7](#)).



Figure 2.7. Button to request clarification or changes by the observer via e-mail.

When all open questions and problems have been clarified, the ACCEPT button ([Figure 2.8](#)) is used to write the observation into the SODIS database and the review process is completed. The observation appears on the HOME page, marked with the green sign indicating the reviewed status.



Figure 2.8. Accepting the review.

For negative observations, some of the above points do not apply, but the general procedure is similar to that for a positive observation.

If the observation turns out to be unreliable, the reviewer deletes it via the DELETE button ([Figure 2.9](#)).

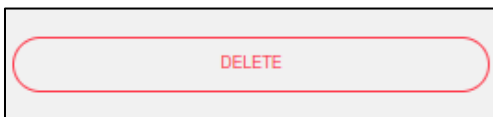


Figure 2.9. Delete an observation.

2.4 How does SODIS export work?

One of the most important functions of SODIS is the export function, which generates an XML file in Occult4 format for each event. An event includes all observations stored in SODIS (positive and negative, at least one positive observation is required) belonging to a particular occultation. In the following, the principles of the export function are described and an example is given.

Note: The export function is primarily an administrator function. However, local export will be available to all with reviewer privileges, and selected reviewers will also be authorized to submit final data to D. Herald.

2.4.1 SODIS export function

After an observation is accepted in the review process, an associated file is stored in the SODIS system. Using the EXPORT button (Figure 2.10), an administrator/reviewer automatically converts *all* SODIS observation entries for a given event into a XML file that contains all the information required by Occult4. This file is locally saved.

ID	Date	Predicttime	AstNo	AstName	Occ	Duration	CC	Observer	ObsMeth	Review Status	
394	2023-01-19	2023-01-19, 00:13:58	325	Heidelberga	O+	1.7	GB		Analogue & digital video	✓ Finished	<input type="button" value="REVIEW"/> <input type="button" value="DELETE"/> <input type="button" value="EXPORT"/>

Figure 2.10. REVIEW page showing a finally reviewed observation, export button in green.

The processor then uses an editor to check the generated XML file to ensure that all Occult4 requirements are met (Figure 2.11).

```

<Observations>
  <FileVersion>2.7</FileVersion>
  <Event>
    <Date>2023|01|19|00.0</Date>
    <Details>
      <Star>UCAC4|596-044525|</Star>
      <Asteroid>325|Heidelberga|</Asteroid>
    </Details>
    <Observations>
      <Observer>
        <ID>
          1|Neustrelitz|DE|+013 53 1 74|31|2|d|a
        </ID>
        <Conditions>|1||</Conditions>
        <D>00 12 42.3|D|0.1|| </D>
        <R>00 12 48.6|R|0.1|| </R>
      </Observer>
      <Observer>
        <ID>
          2|Leeds|GB|-001 3 53 5 114|28|3|a|a
        </ID>
        <Conditions>
          2|1|11.2||There was a brief drop of 1 or 2 points at 00:14:00 (depending on Tangra processing).
        </Conditions>
        <D>00 14 01.33|D|0.15|| </D>
        <R>00 14 03.03|R|0.15|| </R>
      </Observer>
    </Observations>
    <Added>2023|01|26</Added>
    <LastEdited>2023|01|26</LastEdited>
  </Event>
</Observations>
  
```

Figure 2.11. Example of XML file after export, star and asteroid data are still incomplete.

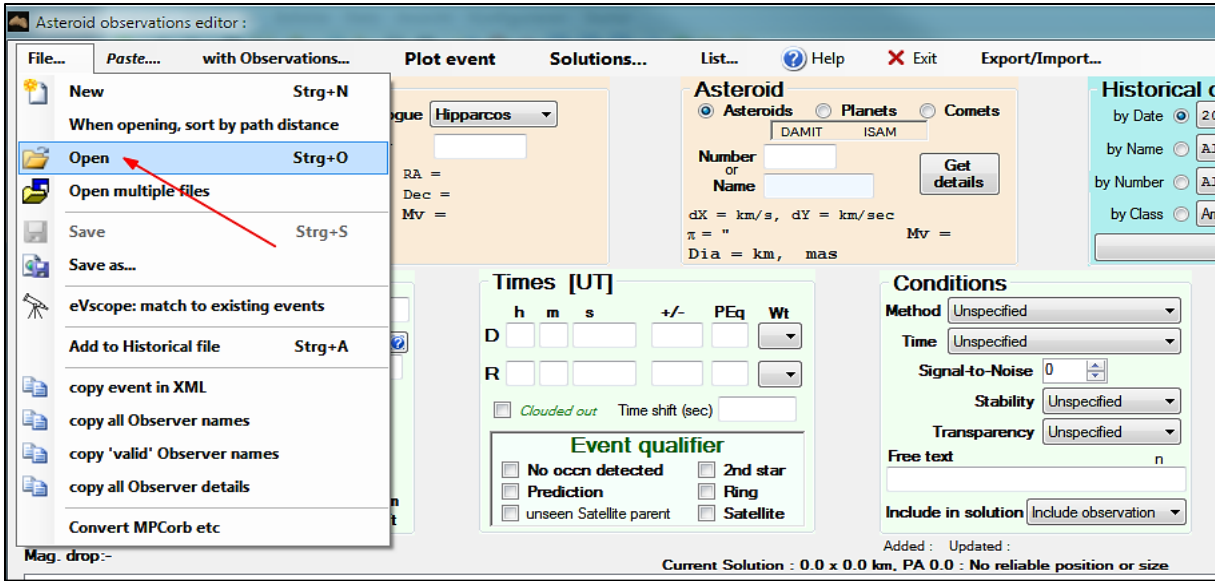


Figure 2.12. Occult4 Asteroid observations editor, open the generated XML file.

The generated XML file is then to be opened in the Occult4 Asteroid observations editor, [Figure 2.12](#). Additional data about the star and asteroid are read in automatically (internet connection required).

In addition, a prediction line must be included. To do this, from the Occult4 event image by pressing F11 ([Figure 2.13](#)) the path coordinates are opened ([Figure 2.14](#)).

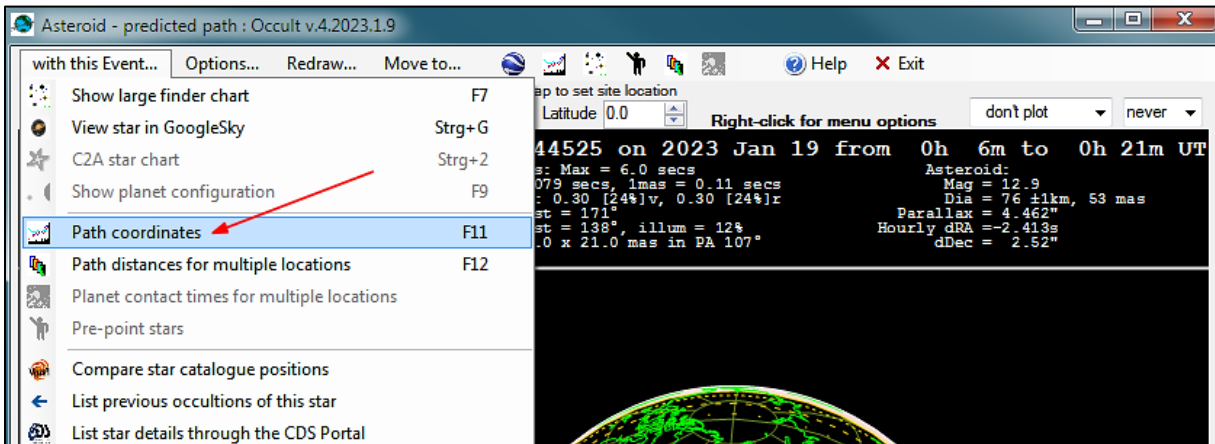


Figure 2.13. Open the path coordinates from the Occult4 event image.

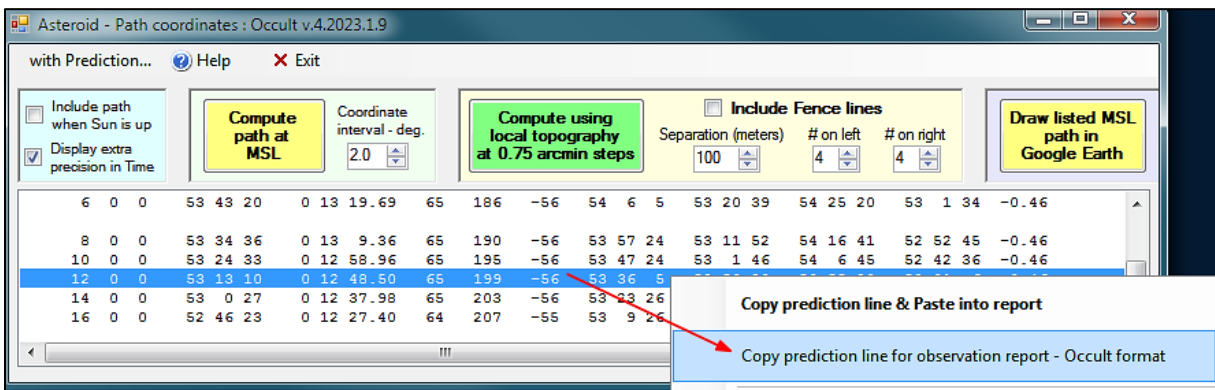


Figure 2.14. Copying the prediction line data to the clipboard.

Right-clicking on a line near the observers' geographic position copies the prediction line data to the clipboard. These data are then inserted with the Asteroid observations editor, see [Figure 2.15](#).



Figure 2.15. Pasting the prediction line.

The Asteroid observations editor now shows the complete event (including the plot window), for an example see [Figures 2.23](#) and [2.24](#). In this state all entries should be checked again.

The final processed and locally stored XML observation files are later submitted to D. Herald (in zipped batches by an administrator).

2.4.2 Example: From the prediction via SODIS into the Occult4 database

In the following an example is presented describing the way of an event from the prediction through SODIS into the Occult4 database. The event is "(303) Josephina occults UCAC4 598-042402 on 2023-Jan-05 at 01:40 UT". [Figure 2.16](#) shows the Occult4 prediction.

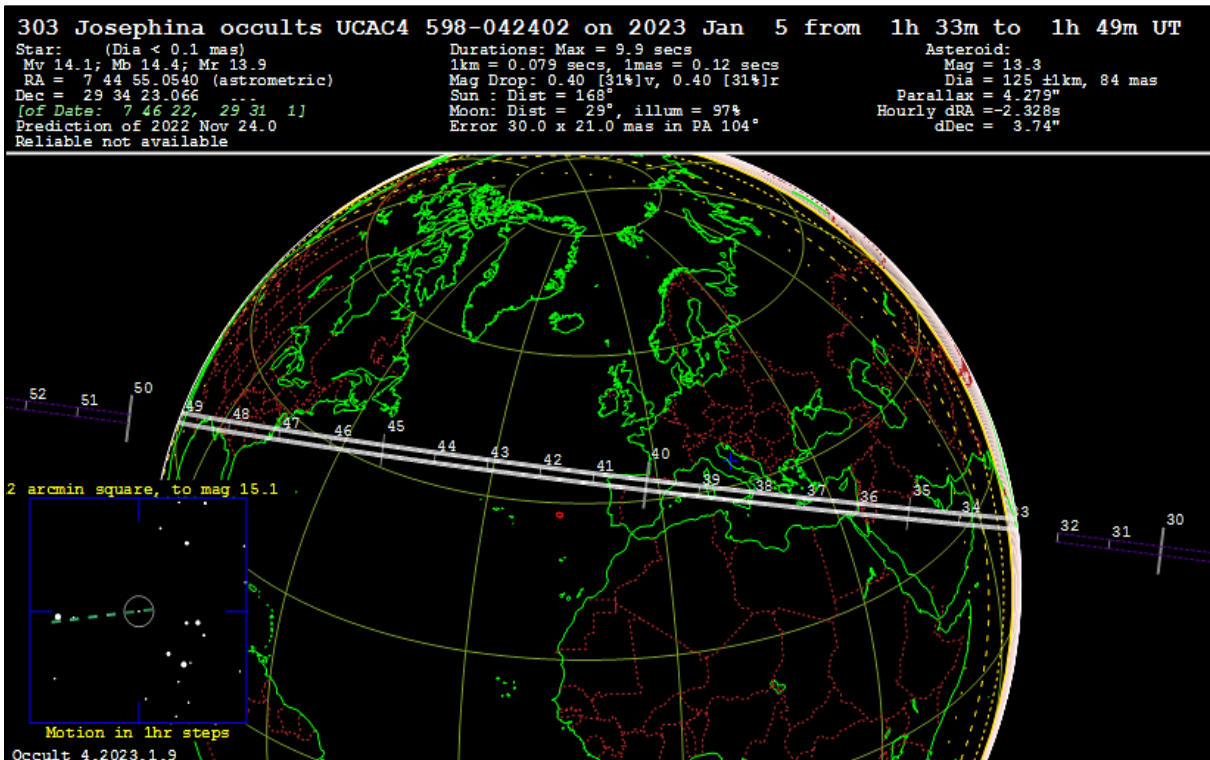


Figure 2.16. (303) Josephina Occult4 transatlantic event prediction.

In OccultWatcher (and OWC), seven observers announced stations (Figure 2.17).

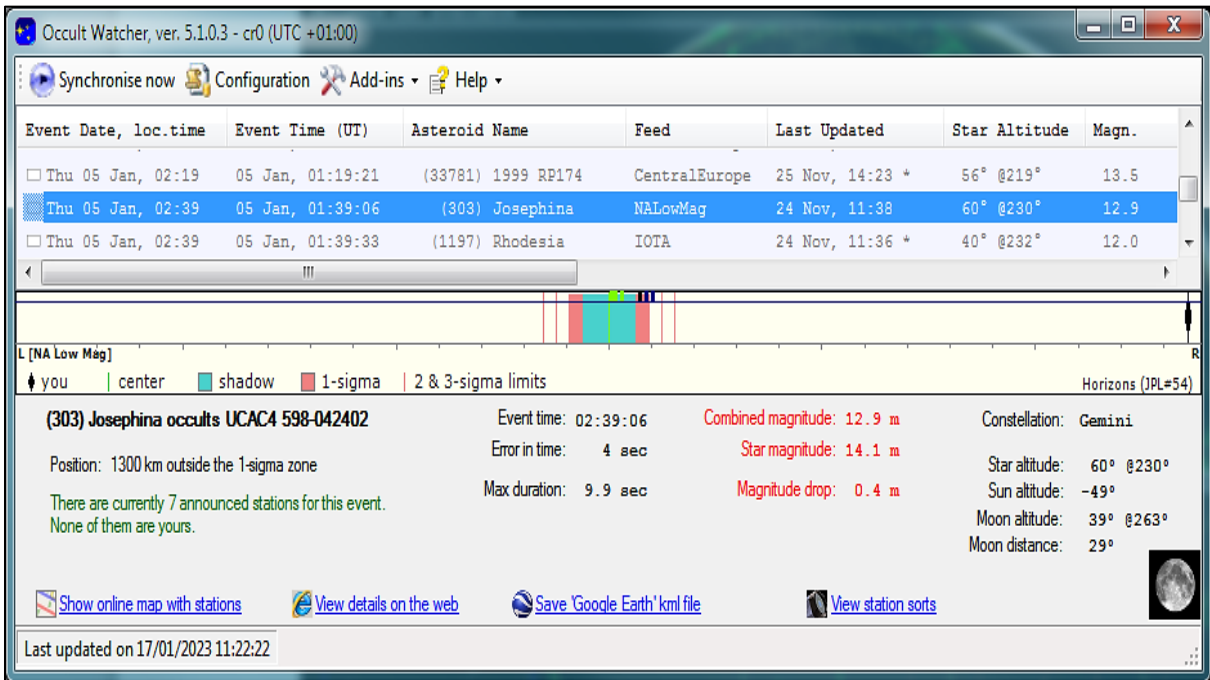


Figure 2.17. OccultWatcher stations for the (303) Josephina event (the transatlantic station cannot be seen).

In the result, there were three observers with no reports (Collada, J., Garcia, F., and Jprat) and one with “no observation” (Stuart, P.C.). As the latter observed from the USA, a report from him would not appear in SODIS and would have to be integrated into the Occult4 database by D. Herald. Three event detections were reported from Europe, which can be easily found in SODIS thanks to the filter function (Figures 2.18 and 2.19).

ID	Date	Predicttime	AstNo	AstName	Occ	Duration	CC	Observer	ObsMeth	Review Status
288	2023-01-05	2023-01-05, 01:39:32	303	Josephina	O+	6.4	ES	Ricard Casas	Analogue & digital video	✓ Finished
285	2023-01-05	2023-01-05, 01:39:32	303	Josephina	O+	7.59	ES	Jordi Marco	Sequential images	✓ Finished
283	2023-01-05	2023-01-05, 01:39:49	303	Josephina	O+	7.00	ES	Oscar Canales Moreno, Angel Rivera et al.	Analogue & digital video	✓ Finished

Showing 1 to 3 of 3 entries (filtered from 258 total entries)

Figure 2.18. SODIS HOME page with the three European (303) Josephina detections.

As can be seen in Figure 2.19, all reviews have been completed. Since reviewers have the possibility to take a look at the reviews even if they have already been completed, we go to the REVIEW page, Figure 2.19.

As an example Figures 2.20 and 2.21 show the review page of J. Marco’s observation. It turns out that the verification was simple, apparently without additional enquiries and discussions with the observer. This also means that the observer has fulfilled all SODIS reporting requirements from the beginning.

The screenshot shows the SODIS REVIEW page with a search filter set to 'AstNo: 303'. The table below displays the filtered results:

ID	Date	Predicttime	AstNo	AstName	Occ	Duration	CC	Observer	ObsMeth	Review Status
288	2023-01-05	2023-01-05, 01:39:32	303	Josephina	O+	6.4	ES	Ricard Casas	Analogue & digital video	Finished
285	2023-01-05	2023-01-05, 01:39:32	303	Josephina	O+	7.59	ES	Jordi Marco	Sequential images	Finished
283	2023-01-05	2023-01-05, 01:39:49	303	Josephina	O+	7.00	ES	Oscar Canales Moreno, Angel Rivera et al.	Analogue & digital video	Finished

Showing 1 to 3 of 3 entries (filtered from 265 total entries)

Figure 2.19. The events on the REVIEW page, the filter is set to select the (303) Josephina reports.

The screenshot shows the 'Review Entry by Jordi Marco' page with the following details:

- Occultation:** Positive
- Date:** 01 / 05 / 2023
- Predictdate:** 01 / 05 / 2023
- Predicttime:** 01 : 39 : 32 AM
- Observer 2:** (empty)
- Star:** UCAC4 598-042402
- Asteroid:** Josephina
- No:** 303
- Nearest City:** Barcelona
- Country Code:** ES
- Latitude:** +041 23 57.8
- Longitude:** +02 09 40.2
- Altitude:** 77 m
- Datum Type:** WGS84
- Telescope:** SCT
- Aperture:** 23.5 cm
- Focal Length:** 77.6 cm
- Obs Method:** Sequential Images
- Exp Time:** 0.4 s
- Start Obs:** 01 : 37 : 30
- End Obs:** 01 : 41 : 30
- D:** Main Star
- D Time:** 1 : 39 : 31
- Acc_D:** 0.72
- Duration:** 7.59 s
- R:** Main Star
- R Time:** 1 : 39 : 38
- Acc_R:** 0.72
- Time Source:** NTP
- Camera:** ZWO ASI120MM
- Signal/Noise:** 2.67
- Wind:** no
- Temp:** 7 °C
- Transparency:** Clear
- Seeing:** Slight flickering
- Comment:** Time source: NTP Meinberg (offset 1,9ms)
- D_WT:** Not Set
- R_WT:** Not Set
- Timeshift:** (empty)
- Plotcode:** Include observation

Figure 2.20. Review page of J. Marco’s observation, reporting part.

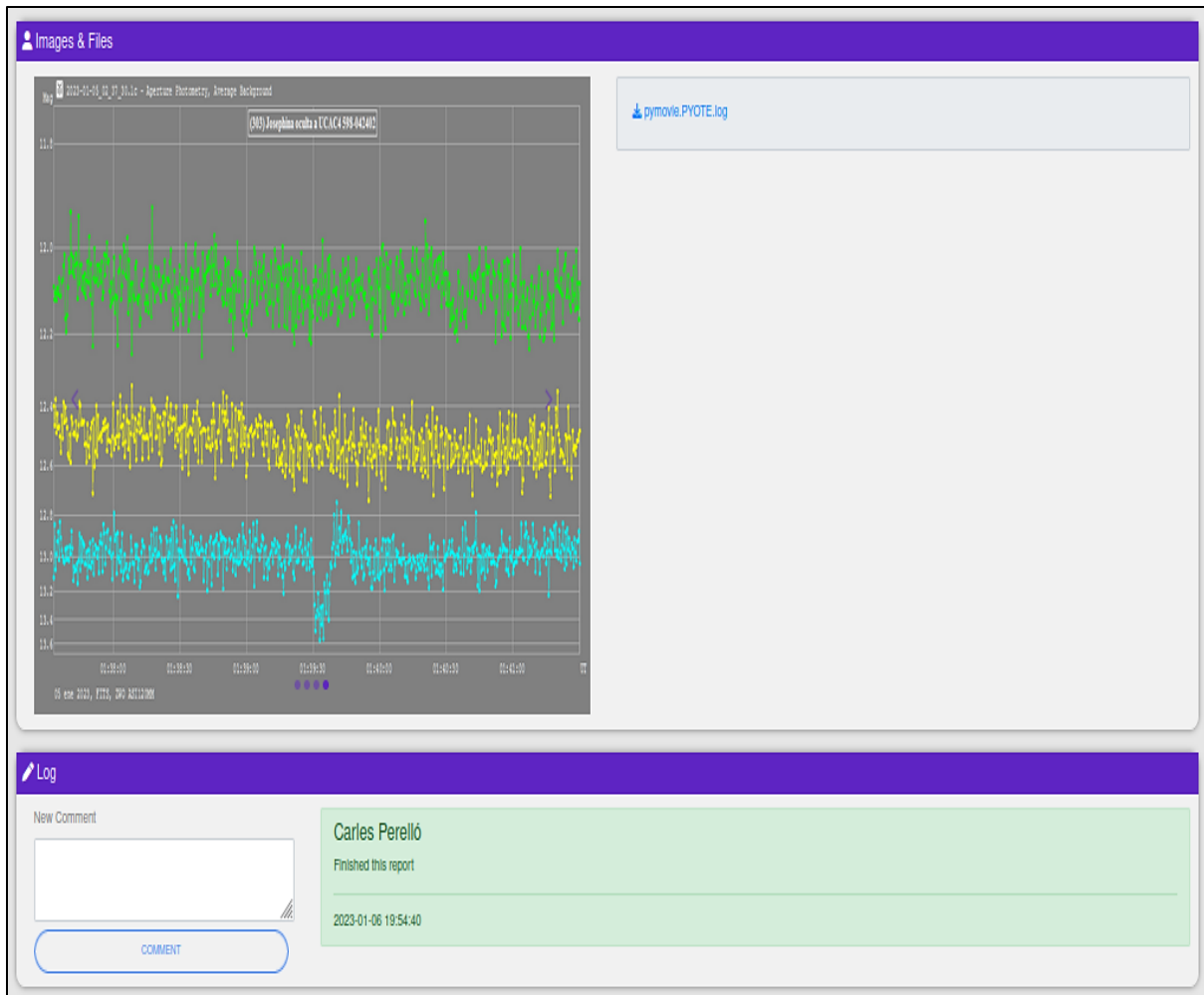


Figure 2.21. Review page of J. Marco’s observation showing the images and files section and at the bottom the log of the review.

[Figure 2.20](#) shows an observer's comment on the timing of the recording (the field for the time source is correctly set to NTP). While often unnecessary comments are made by the observer that later have to be revised or deleted by the SODIS administration, the comment in this case may be useful.

When a review is completed, the next step is to go to an SODIS export processor who will look at whether the review is in order and in particular compatible with the Occult4 requirements. Then, as described in [Chapter 2.4.1](#), using the EXPORT button ([Figure 2.22](#)) all single observations of the particular event are written into a XML file which is locally stored.



Figure 2.22. Export button on the REVIEW page.

This file is opened in the Occult4 Asteroid observations editor to add a prediction line (as described in [Chapter 2.4.1](#)), the star and asteroid data are automatically inserted over the internet.

The complete XML file of the observation is saved from the observations editor, for the event of (303) Josephina it looks as follows:

```

<Observations>
<FileVersion>2.7</FileVersion>
<Event>
<Date>2023|1|5|1.1</Date>
<Details>
  <Star>UCAC4|598-
    042402|3|879056011650878208|7.7486261023|29.573073854|0.16|0.13|0.01|0|7.77286331|29.5170508|14.
    43|14.11|13.63|0</Star>
  <StarIssues>1.10|0|0|0|1.20|10|0.00|0.00|0.00|0.00</StarIssues>
  <Asteroid>303|Josephina|-7.10100329|0.87635660|-0.0010394|-0.0006692|0.0000014|-
    0.0000003|4.27941|0.00015|101.6|5.0|13.29</Asteroid>
  <EventFits>
  <SolveFlags>1|1|0|0|0|1|1|0|0</SolveFlags>
  <EllipticFit>0.0|0.0|101.6|101.6|0.0|0|1|0|0.0|0.0</EllipticFit>
  <EllipseUncertainty>2.3|8.4|||</EllipseUncertainty>
</EventFits>
</Details>
<Observations>
  <Observer>
  <ID>1|Ricard Casas||0|Sabadell|ES|+ 2 7 14.3|+41 32 22.1|165| |20|3|a|a</ID>
  <Conditions>1|1|2.28||</Conditions>
  <D> 1 39 31.9|D|0.5||| </D>
  <R> 1 39 38.2|R|0.5||| </R>
  </Observer>
  <Observer>
  <ID>2|Jordi Marco||0|Barcelona|ES|+ 2 9 40.2|+41 23 57.8|77| |24|3|d|b</ID>
  <Conditions>2|1|2.67||Time source: NTP Meinberg (offset 1,9ms)</Conditions>
  <D> 1 39 31.1|D|0.7||| </D>
  <R> 1 39 38.7|R|0.7||| </R>
  </Observer>
  <Observer>
  <ID>3|Oscar Canales Moreno|Angel Rivera|1|Lecinena|ES|- 0 35 12.1|+41 48 1.2|544| |20|3|a|a</ID>
  <Conditions>1|1|||</Conditions>
  <D> 1 39 48.4|D|0.2||| </D>
  <R> 1 39 55.4|R|0.2||| </R>
  </Observer>
  <Prediction>4|+ 2 0 0. |+41 16 13. | 1 39 33.50|JPL#54:2022-Nov-22</Prediction>
</Observations>
<Added>2023|1|15</Added>
<LastEdited>2023|1|15</LastEdited>
</Event>
</Observations>

```

In the XML example above, the various sections are marked with different colours. The red enlarged section describes the observation of J. Marco. For example, it can be seen (yellow highlighted) that there is under <Conditions> the comment regarding the timing of the observation, also indicated by the “b” = “Time source NTP” under <ID>. Also, no weighting and plotcode options were set - all the regarding fields are in default (empty) state. The structure and format of the XML file are described in the appendix, [Chapter 5.1](#).

The XML observation files are transmitted to D. Herald. There the observation is checked again and possible observations from other regions are added. The elliptical fit (including existing shape models) is finalized and the astrometric solution is derived, followed by adding the observation into the Occult4 database.

The event can be found with the editor (Figure 2.23) and from there also be plotted (Figure 2.24).

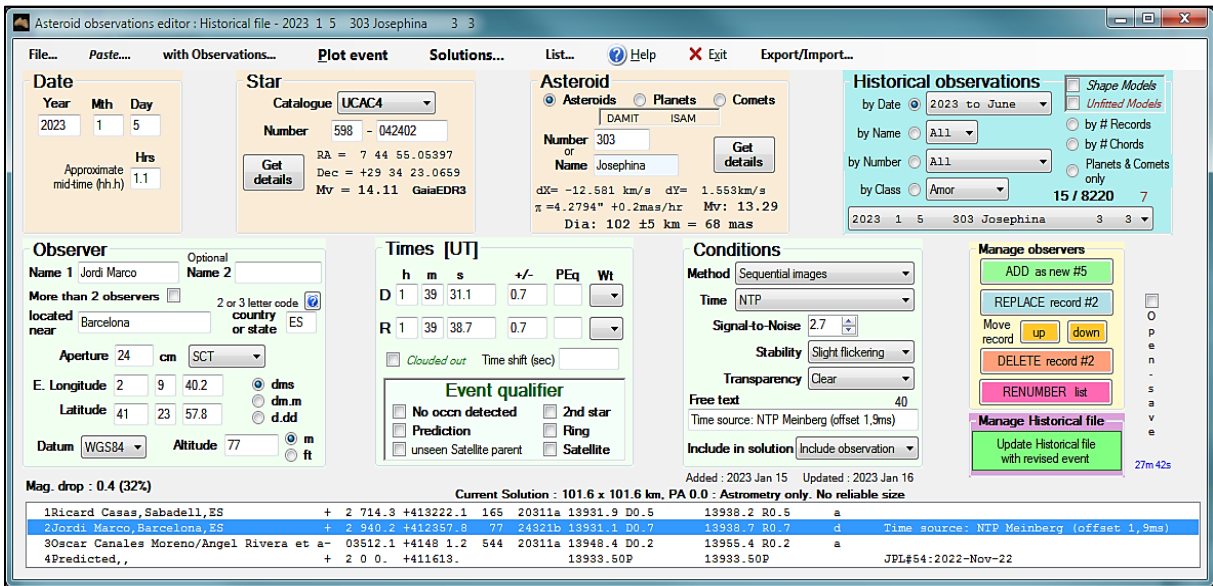


Figure 2.23. The (303) Josephina event opened in Asteroid observations editor.

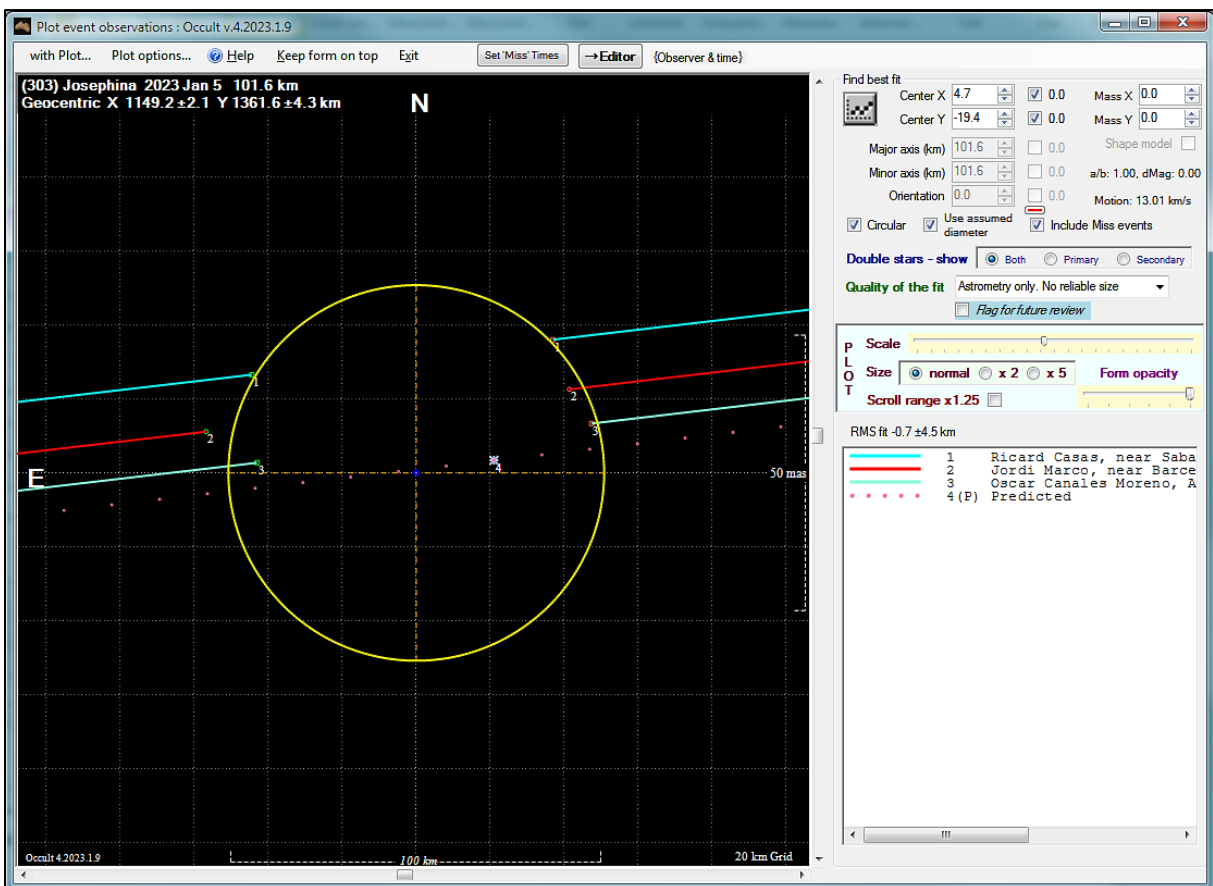


Figure 2.24. Plot of the (303) Josephina event.

D. Herald will transmit the data to NASA PDS and to the MPC. The event remains accessible in the Occult4 database. If the cooperation with CORA will work, also there the event will be accessible. In SODIS, it can be seen on the HOME page and for the reviewers also on the REVIEW page. In addition, Observers are encouraged to upload their lightcurves to D. Herald to be transmitted to Vizier.

3 Occultation data reduction issues

The following section cannot describe the complex data reduction with the corresponding tools in detail. The purpose is rather to point out some common mistakes and issues.

The main objective of the data reduction process is to ensure the quality of data output. [Figure 3.1](#) shows what the data quality depends on.

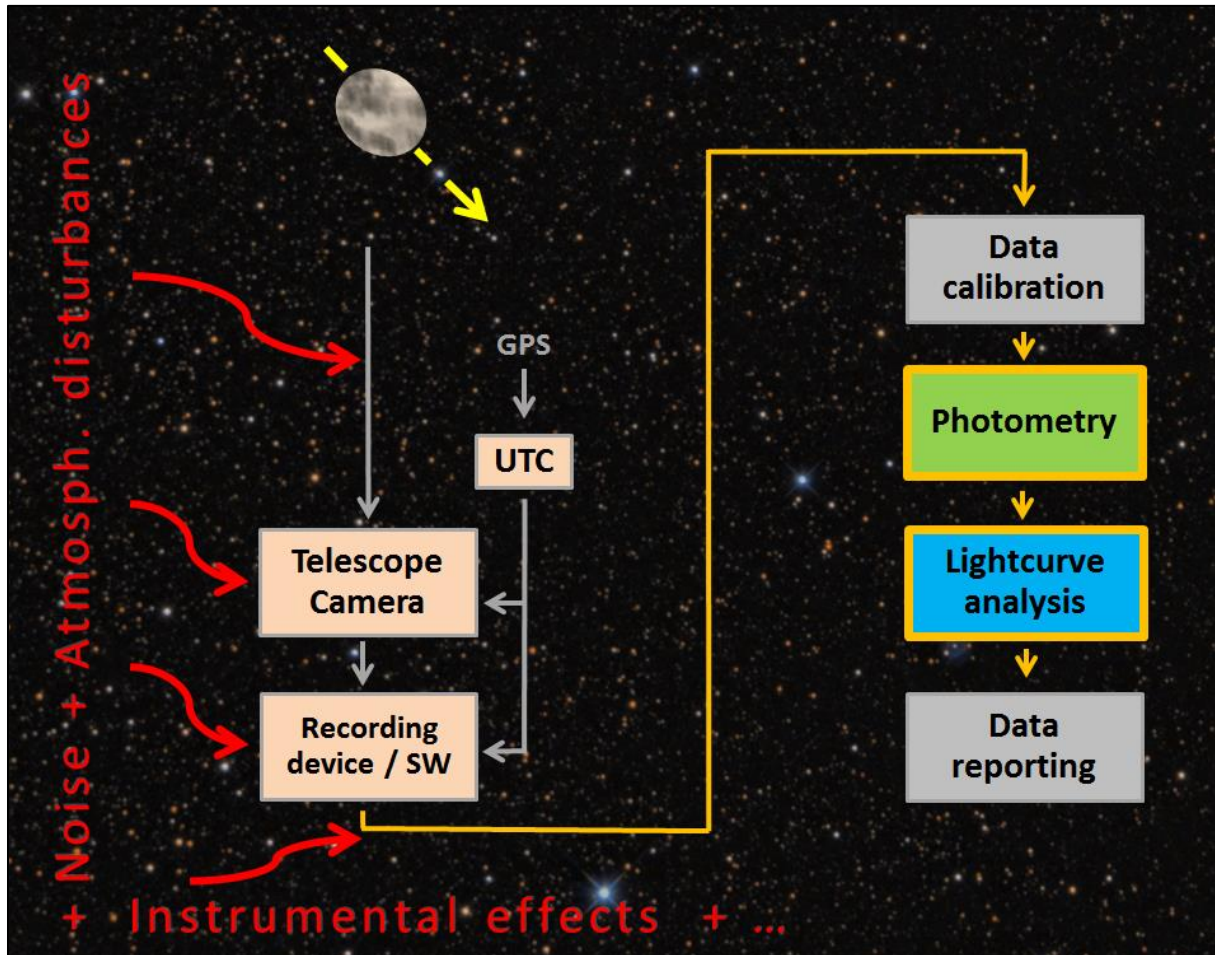


Figure 3.1. Occultation recording hardware and data reduction pipeline.

Including the light curve analysis, all steps shown in [Figure 3.1](#) are performed by the observers and the result is transmitted to SODIS. Thus, the reviewer finds a result that has already been assessed by the observer in terms of its plausibility and that he now has to assess again for his part. In the following, the focus is on the challenges that need to be overcome:

- Hardware related issues
- Photometry issues
- Lightcurve analysis issues

3.1 Hardware related issues

Besides noise of different origins ([Figure 3.1](#)), the correct timing of the recording, including dealing with possible instrumental delays, is a fundamental aspect. Effects of temporal delays depend on the hardware used and must be handled by the reduction software. The reviewer must check which

hardware was used by the observer, whether instrumental effects are possible and whether the observer has taken them into account correctly in the evaluation.

By observers, a variety of camera types are used, the reviewer should know their working methods and the differences between them. Some very common cameras are shown in [Figure 3.2](#).

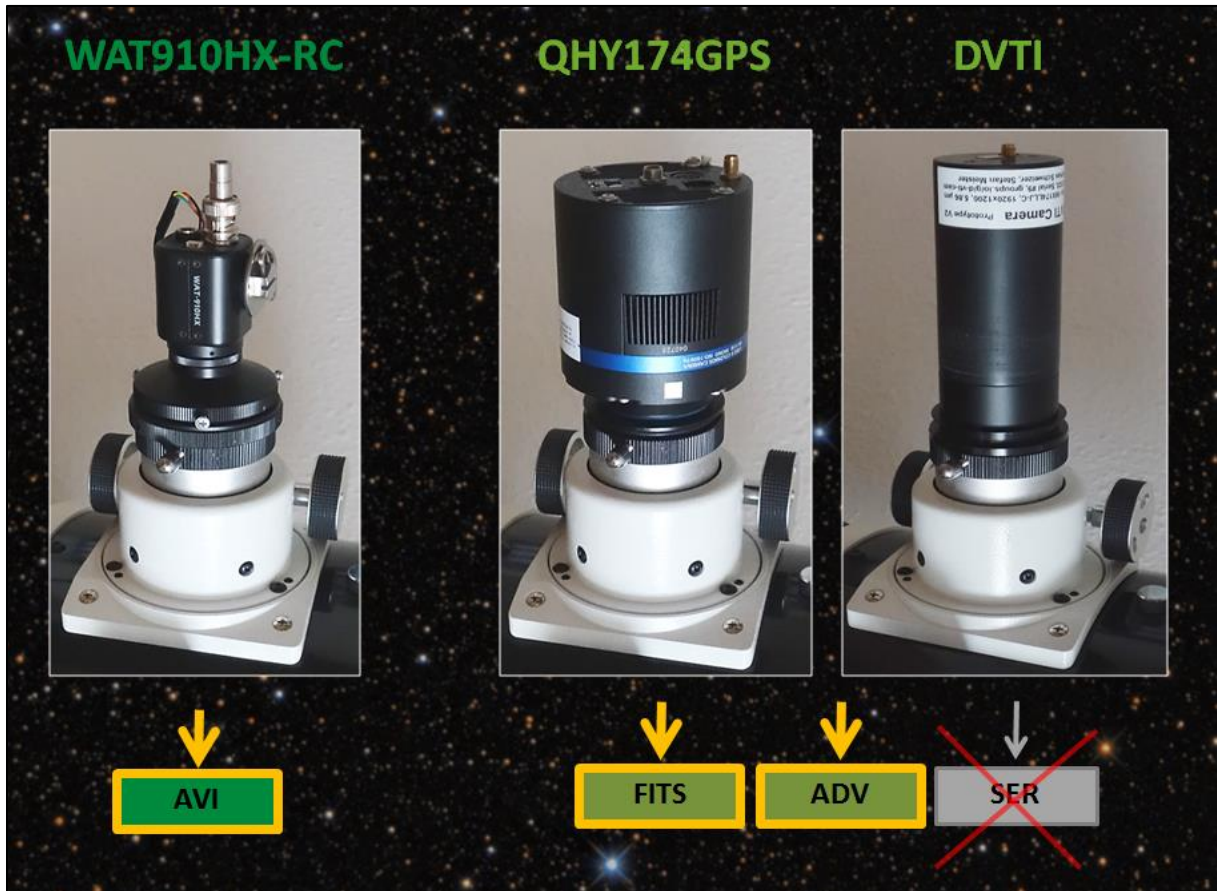


Figure 3.2. Common cameras to record occultations (because of disadvantages SER recording should be avoided, see [Chapter 4](#) for related links).

Most of the digital (CMOS) cameras often used are not directly designed for occultation recording, usually they have a **rolling shutter** (an exception is the QHY174GPS camera, which has a global shutter). With rolling shutter cameras attention must be paid to possible delays (which are often unknown to the observers) depending on the vertical position of the star on the sensor.

Analogue cameras are still used today, often because of their sometimes higher sensitivity compared to CMOS cameras. The **video time inserters (VTIs)** required for analogue cameras and also the **video grabbers** may require additional attention (possible instrumental delays). The usual analogue cameras have well known time delays (see links in [Chapter 4](#)), depending on the frame integration. Common data reduction software is able to deal with these instrumental delays.

Also possible issues due to external **GPS modules** or **NTP setups** must be checked carefully too (only the QHY174GPS camera has an inbuilt GPS-time-stamping). Especially with NTP setups not using Meinberg (or similar) software there can be significant temporal issues.

3.2 Photometry issues

The photometry of an occultation recording is the key to ensure a good basis for extracting occultation times later. There are not infrequent cases where it is useful to repeat the photometry with different settings and sometimes with alternative photometry software ([Figure 3.3](#)).

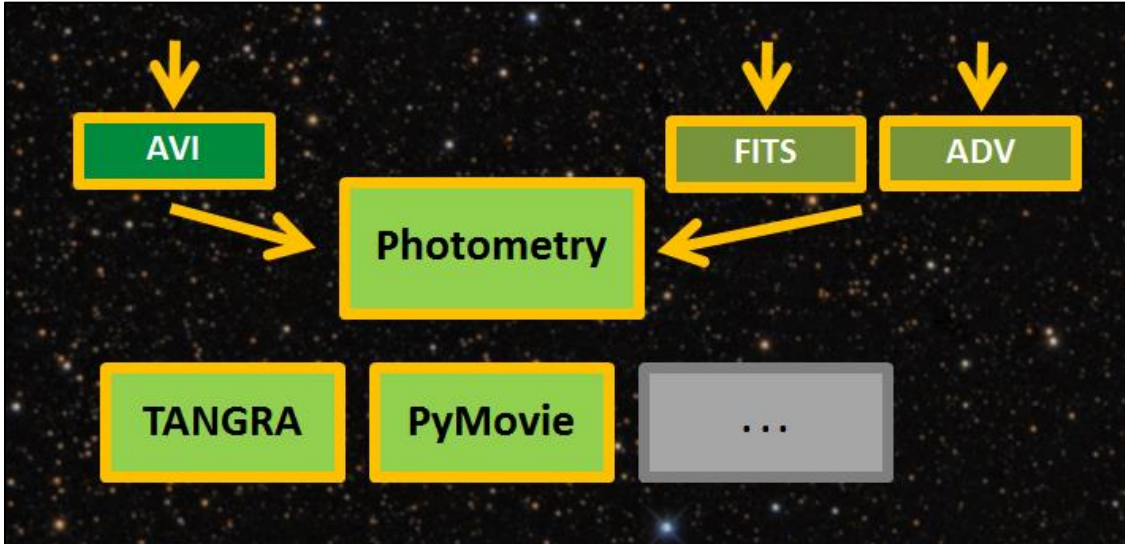


Figure 3.3. Common photometry software.

When recording occultations, there are many possible problems that affect or complicate photometry - only some of them are listed below. It is not intended to describe the photometry programmes itself in detail. For this, consult the relevant web resources and programme guides.

3.2.1 Tangra

Tangra is a very powerful tool for the photometry of occultation recordings. Normally, Tangra's default settings work well. Tangra timestamps are always midevent times. [Figures 3.4](#) to [3.14](#) show typical examples of what can go wrong with photometry, mainly Tangra related.

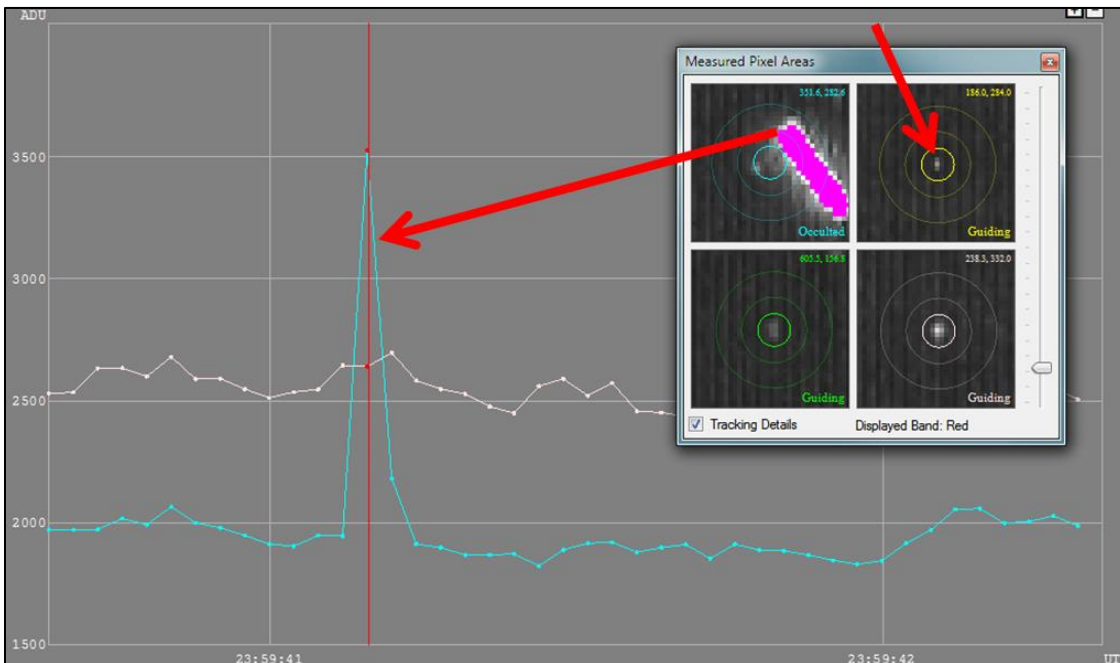


Figure 3.4. Artificial satellite and a hotpixel as guiding “star” (yellow aperture).

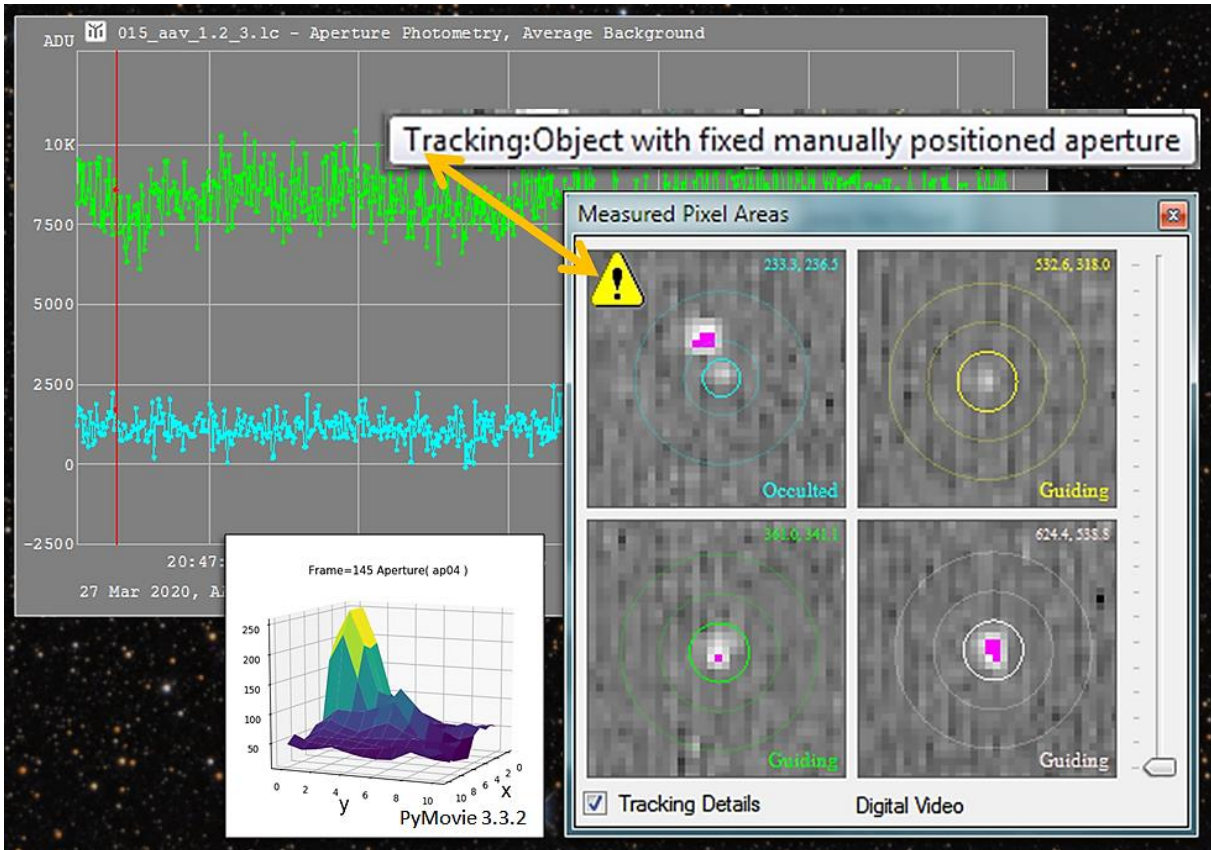


Figure 3.5. Nearby bright stars can disturb the target star photometry and also change the predicted drop; red: saturated stars; weak target stars shall be not “Auto tracked” but using the option “Fixed - Relative to Guiding Stars”, indicated by the yellow exclamation mark.

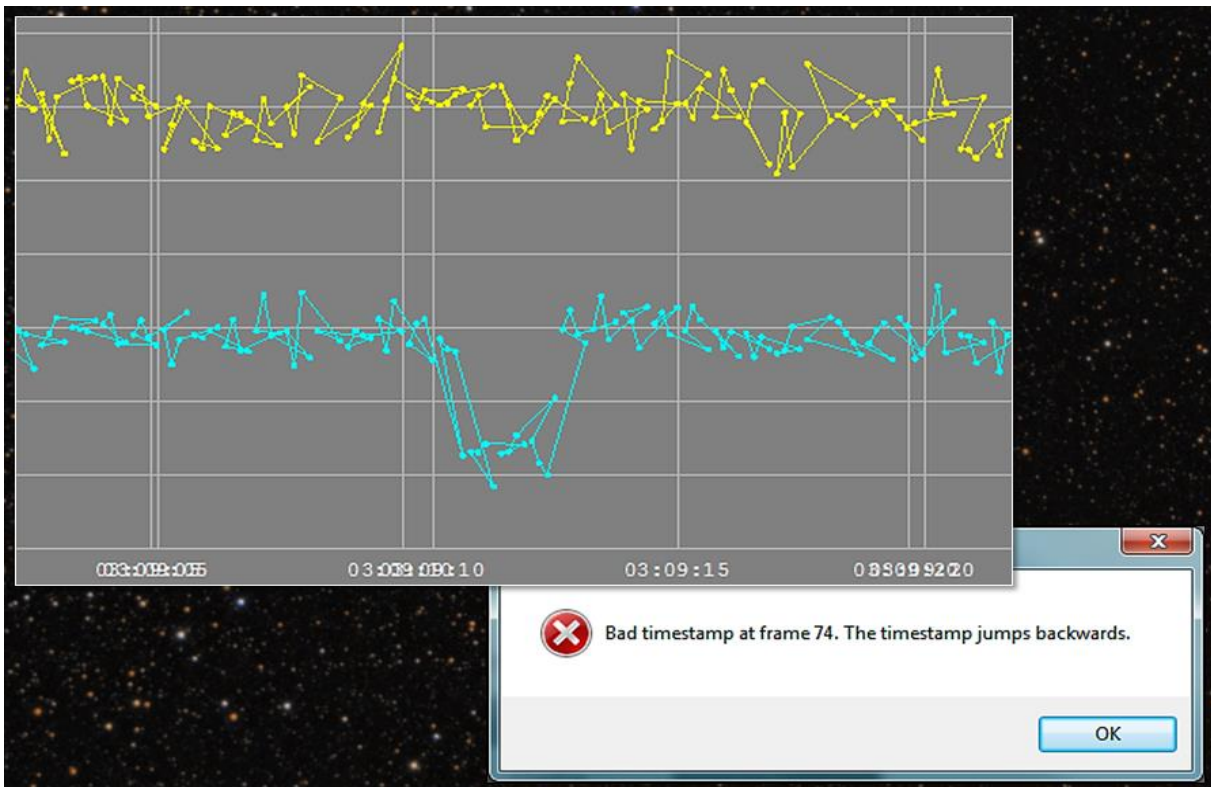


Figure 3.6. Backwards jumping timestamp, all timestamps after frame 74 are wrong.

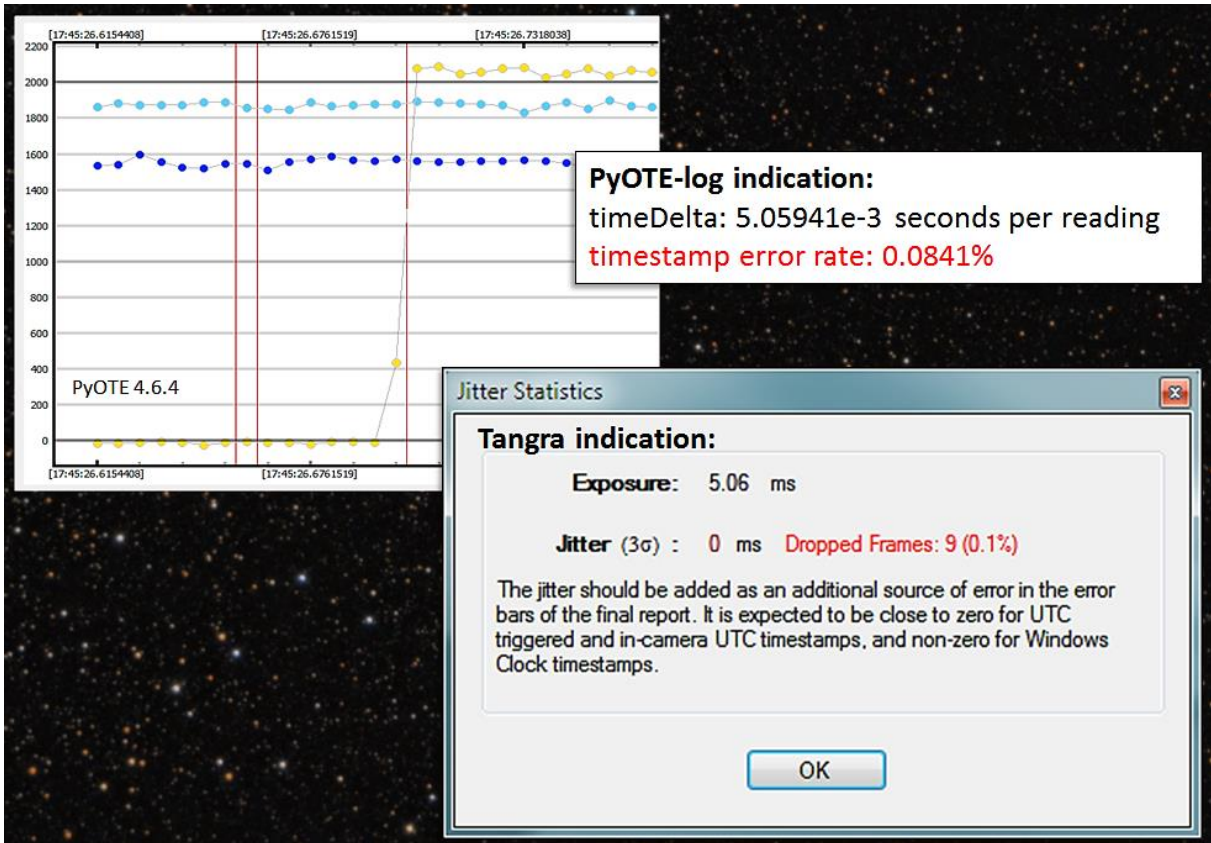


Figure 3.7. Dropped frames: Tangra’s indication versus PyOTE’s indication (red vertical lines, see [Chapter 3.3.2](#)).

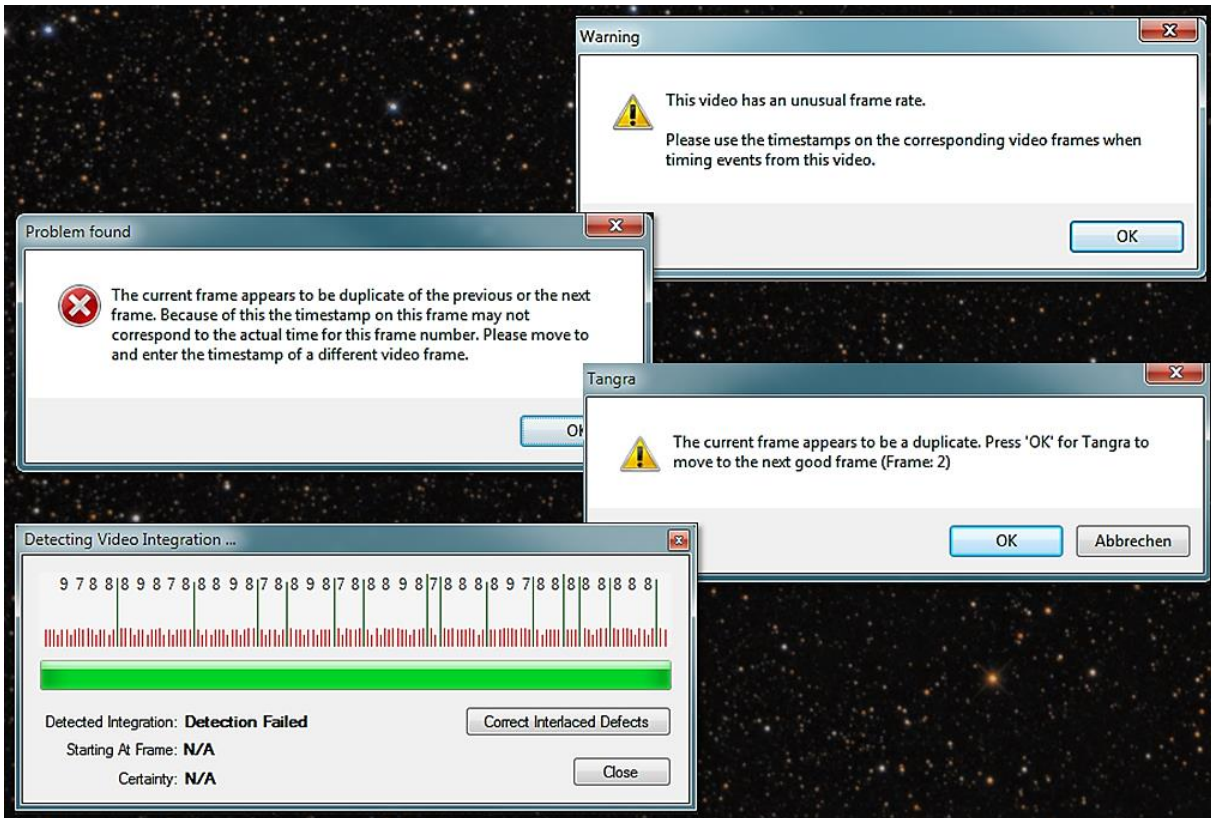


Figure 3.8. Timing and integration issues.

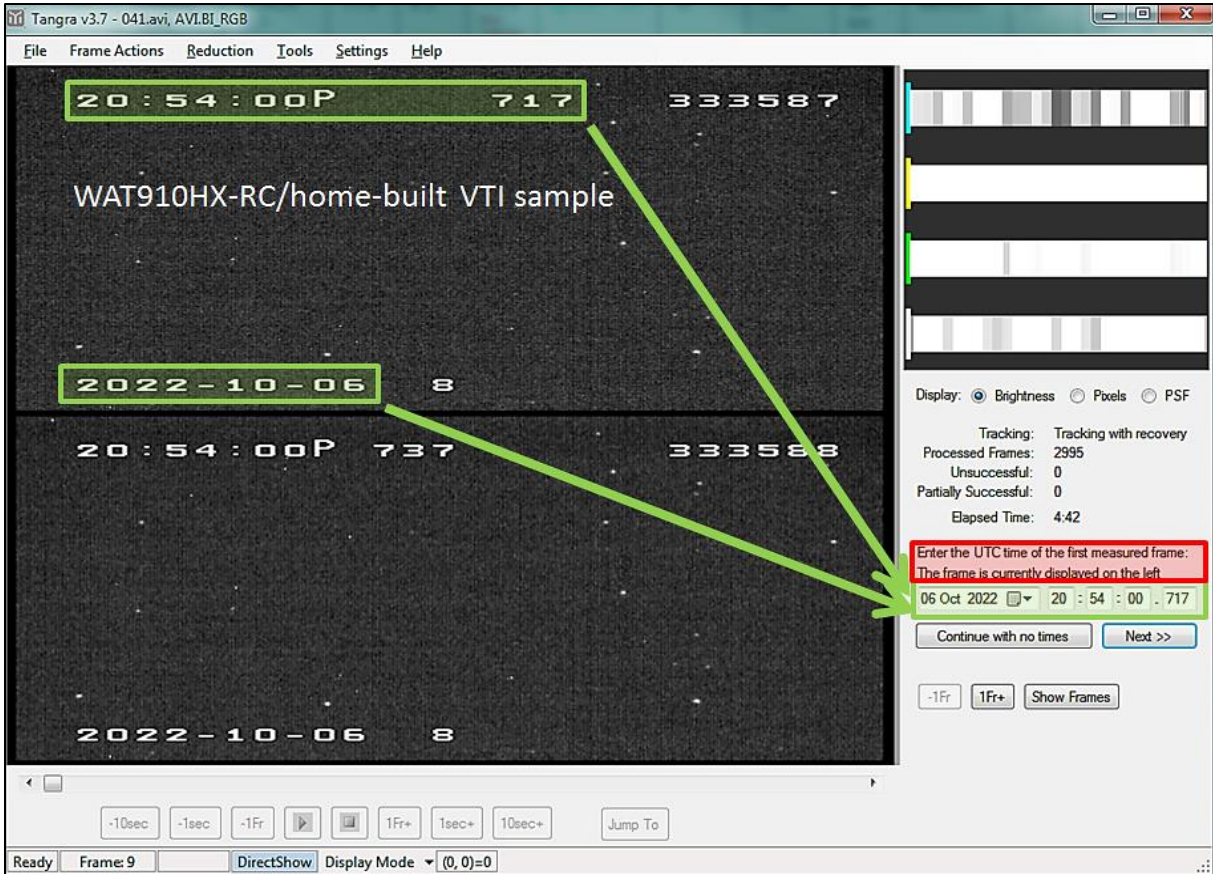


Figure 3.9. Tangra manual timestamps entry, it is easy to enter wrong times here.

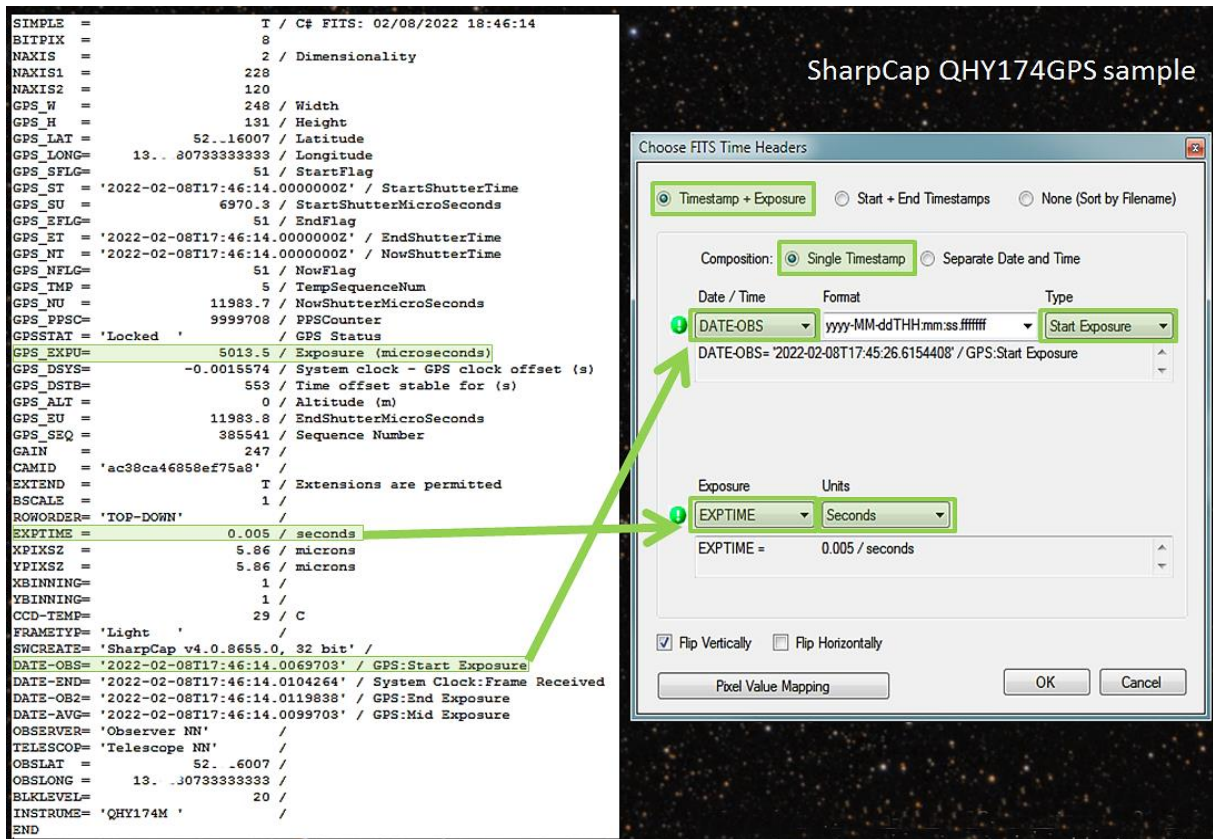


Figure 3.10. Tangra FITS keywords selection for a QHY174GPS camera, incorrect entries are easily possible.

The screenshot shows three columns of settings for the Tangra photometry interface:

- Column 1 (Left):** Reduction method: Aperture Photometry; Digital filter: No Filter; Background from: Average Background.
- Column 2 (Middle):** Reduction method: Aperture Photometry; Digital filter: Low Pass Filter (LP); Background from: Average Background.
- Column 3 (Right):** Reduction method: Aperture Photometry; Digital filter: No Filter; Background from: Median Background.

Below the settings are three colored boxes with text:

- Green box:** Works in most cases (= default settings)
- Yellow box:** Useful to try out: Optimal Extraction Ph. [1], Low Pass Filter, Median Background
- Purple box:** PSF Photometry: More accurat, useful for saturated stars

Figure 3.11. Tangra photometry options, in difficult situations it is recommended to experiment with the different options.

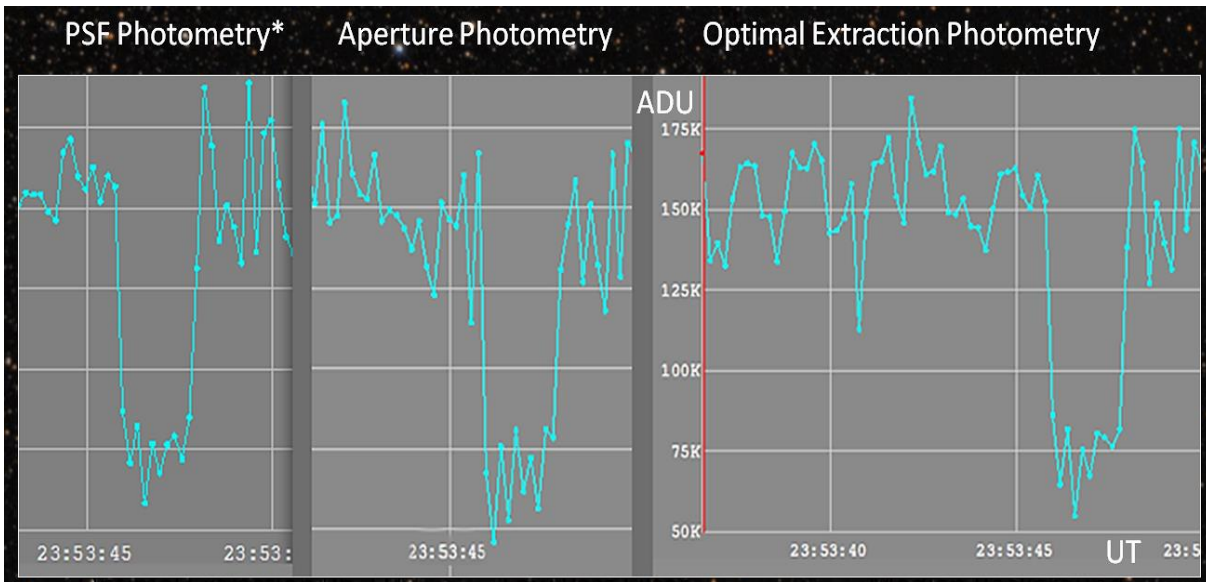


Figure 3.12. Comparison of Tangra's photometry methods (* Numerical Quadrature in Aperture; for all: Average Background, No Filter).

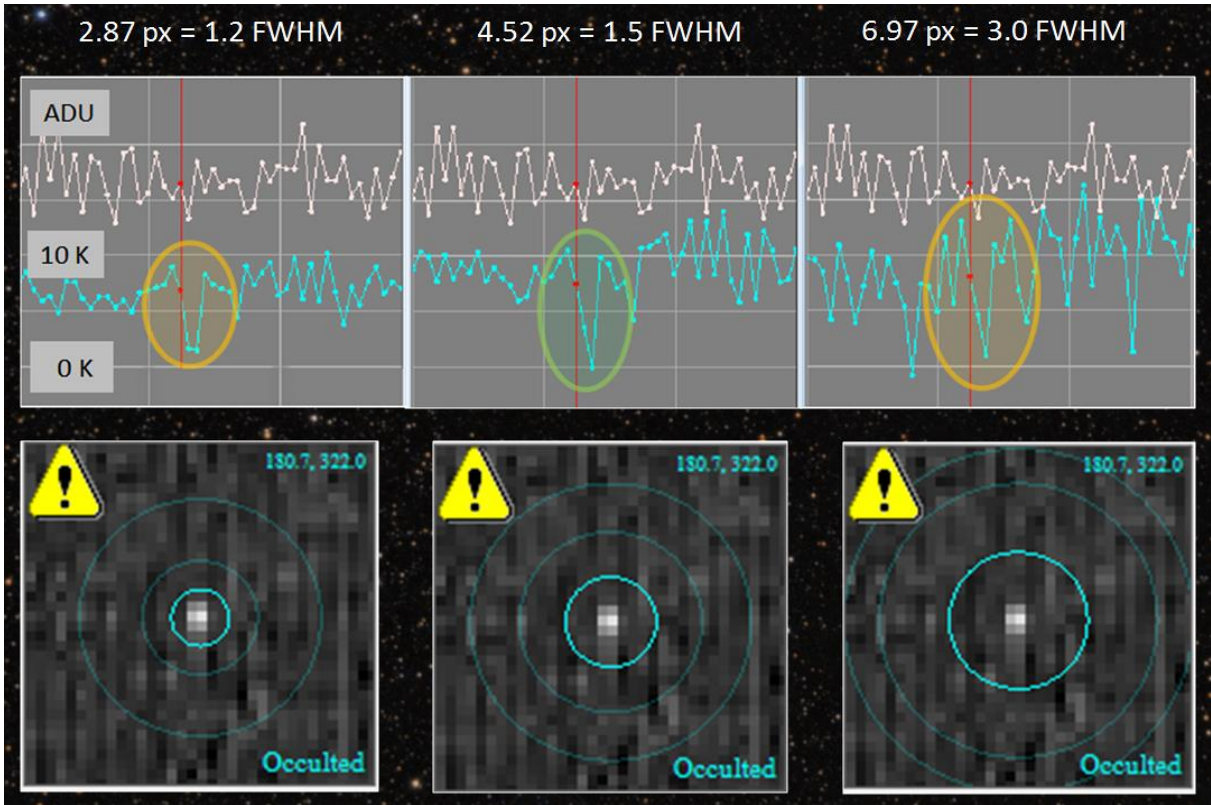


Figure 3.13. Tangra: Role of the size of the target aperture.

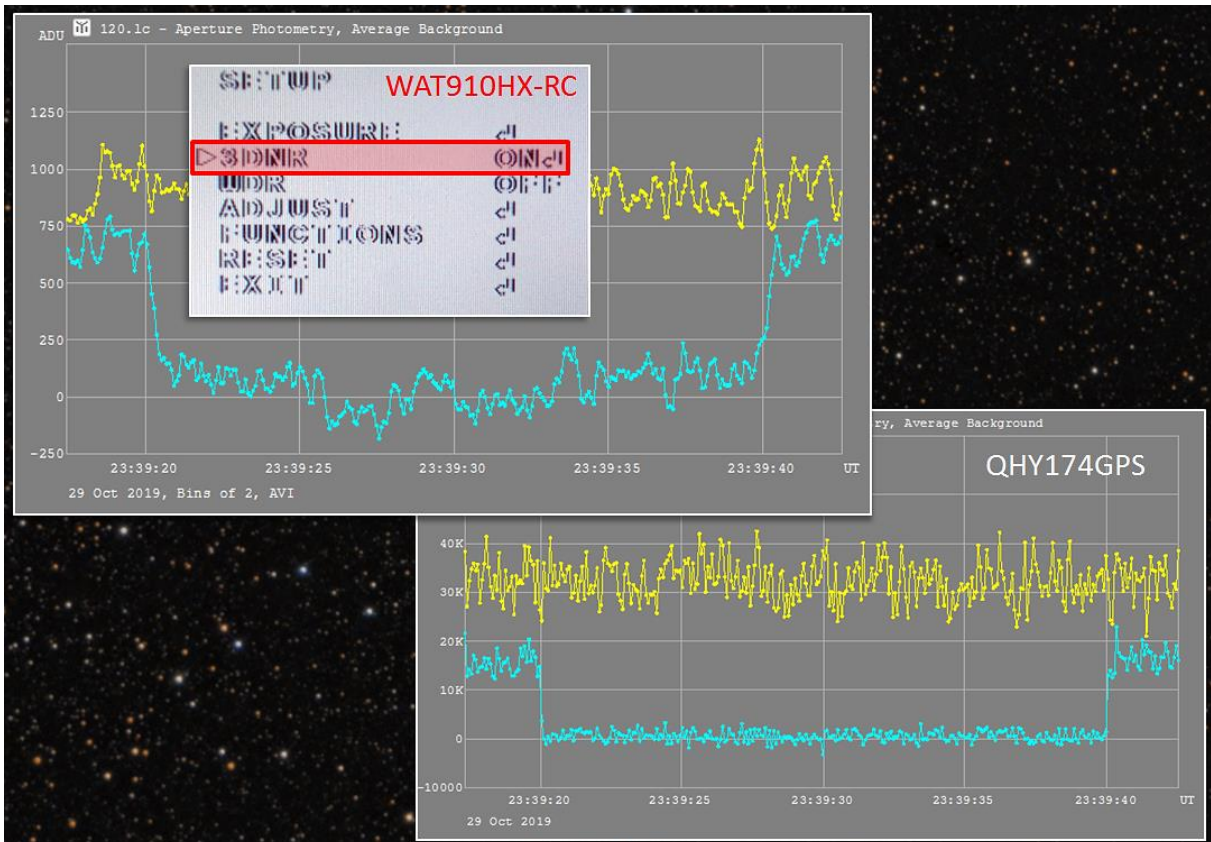


Figure 3.14. WAT910HX-RC incorrectly set, 3DNR was ON, resulting in "gradual" D and R transitions; with the QHY174GPS camera on a second telescope there were no D or R effects.

3.2.2 PyMovie

Compared to Tangra and AOTA, PyMovie (as well as PyOTE) use different approaches to data reduction. This is one of the reasons why both programmes require a certain training period. In any case, these Python programmes are a good alternative and it is worth installing them and familiarising yourself with them. Especially if data reduction with Tangra/AOTA is critical, it is recommended to do a cross-check with PyMovie/PyOTE.

Since there cannot be a complete guide for Tangra/AOTA in this manual, but only hints on critical points, this shall also be done for PyMovie and PyOTE in the same way.

Valid points for PyMovie as well as PyOTE:

- Installation**
 For the installation of the programmes see some hints in the appendix ([5.3 PyMovie/PyOTE installation hints](#)). Note: PyOTE versions 4.2.1, released on 8 February 2022, until version 4.4.8 were buggy (see appendix).
- Help possibilities**
 Both programmes have dedicated help buttons. There is also a very detailed context help: *Right-click on the element in question* ([Figure 3.15](#)). In addition, the programme paths contain PDF documents explaining change logs and also contain documentations. On the global IOTA website one can find several tutorials.
- Settings**
 Normally, the default settings work well. With both programmes it is possible to work with several instances at the same time.

Opening a recording

PyMovie is able to read all of the common data formats used for occultation recordings ([Figure 3.15](#)). FITS sequences containing folders can be opened directly (*“Select FITS folder”*). After opening files of the other formats (*“Open AVI/MOV/SER/ADV/AAV file”*) an *“AVI/MOV/SER/ADV/AAV-WCS folder”* must be created (required for later work with programme features like OCR, WCS, ...). This folder will also contain all the programme outputs.

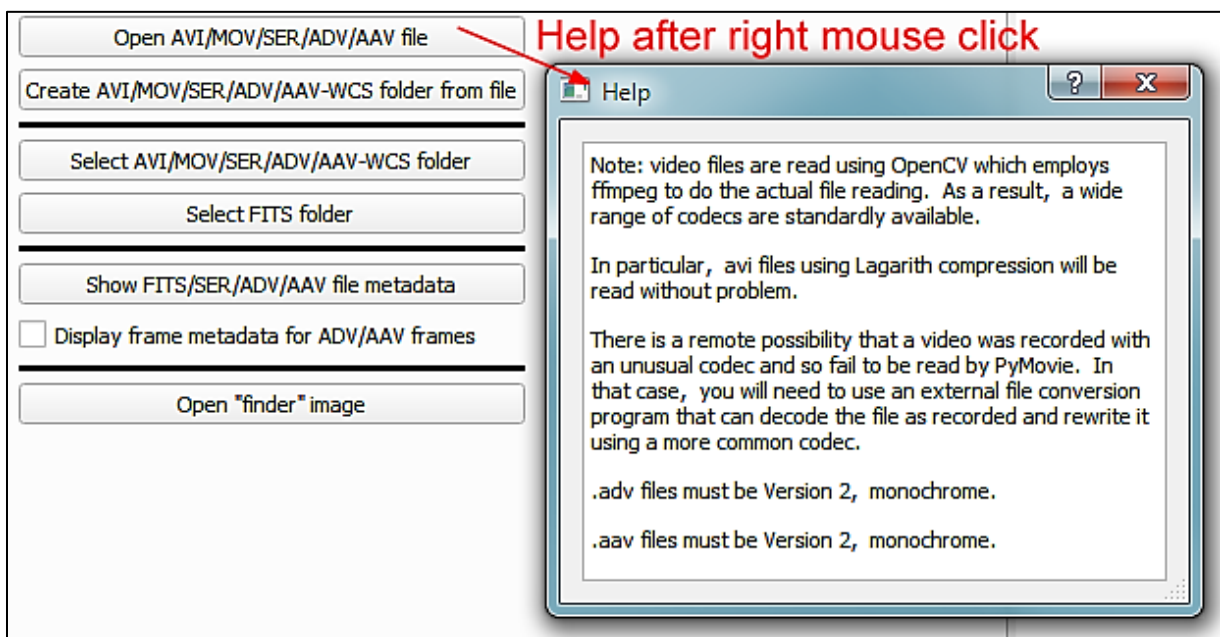


Figure 3.15. PyMovie file opening dialogues and context help example.

Time source

In general, PyMovie (as well as PyOTE) await *Start-of-Exposure timestamps*. From recording data heaving time headers (ideally DATE_OBS) like FITS and ADV, PyMovie reads the times directly with no further requirements to the operator.

For recordings with analogue cameras, PyMovie can handle common VTIs by OCR, see [Figure 3.16](#). For not listed VTIs it is possible to create and save *custom OCR profiles*.

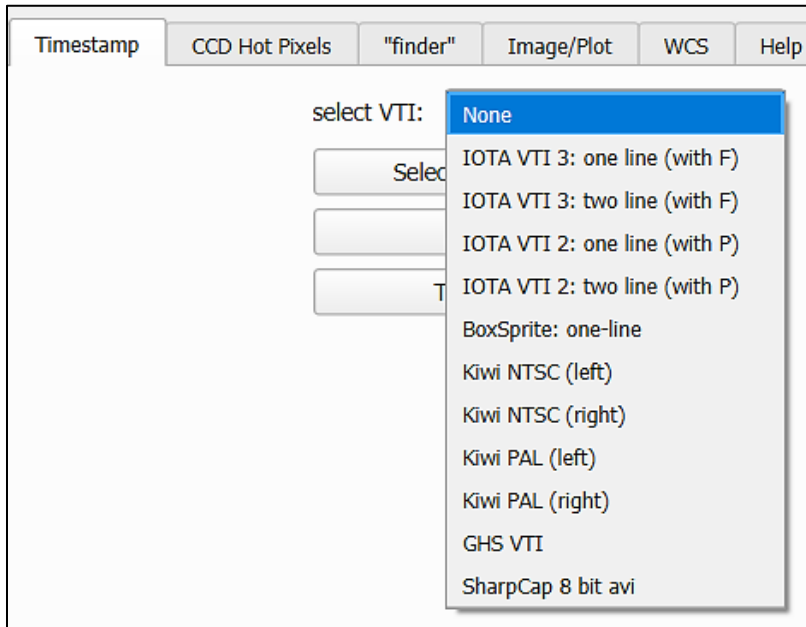


Figure 3.16. PyMovie VTI selection options.

Main image display

On the right-hand side of the programme, the recording is displayed. The possibility to change the histogram (checkboxbox “*Show image contrast control*”) is useful to precisely positioning of the apertures. To keep changes here, the checkbox must be deactivated again after a setting has been made. Changing the histogram does *not* change any data. The various navigation buttons below the image display are self-explanatory.

Setting apertures

Setting of apertures is best explained here: PyMovie/Help/Help for image area (aperture placement, etc):

- “A right-click in a region that does not contain a measuring aperture will cause a context menu to appear that has *Add snap-to-blob aperture* and *Add static aperture (no snap)* menu entries. You will almost always be using the 'snap-to-blob' aperture; *Add static aperture (no snap)* is used for placing an aperture exactly where you want it (i.e., no snap). This will most commonly be used for placing a white aperture (see below) and for placing an aperture on a "finder" image.
- On this same context menu, there are menu items for controlling aspects of the image view itself; the most used menu item will be View all, used after a scroll wheel zoom or left-click-drag-for-pan have been used to adjust the view to return the size and position to the original condition.
- A right-click inside a measurement aperture brings up a context menu that allows you to change properties of the aperture. You will be most concerned with the color of the aperture:

- A **yellow** aperture around a bright star causes that star to be used as a tracking reference. If you select a single star as a tracking reference, translation movements (the image as a whole moves some number of pixels up, down, and sideways) of the star field will be tracked. The aperture constellation as a whole will be translated.
- You can add a second yellow aperture (no more than two are allowed) if there a possibility of field rotation as well as field translation. In this case, tracking equations are used that allow for the aperture constellation as a whole to be both rotated and translated in order to follow the star field.
- A **green** aperture is connected to the threshold setting spinner to make it easier to modify threshold settings. That spinner has the longish title: *set mskth counts above bkavg*.
- A **white** aperture is useful when flash-tags have been recorded in the video. The special thing about a white aperture is that all pixels in the aperture are summed and output as the 'signal' with no background subtraction. Such a signal can be employed by PyOTE to provide an alternative to the timestamp overlay from Video Time Inserters. In addition, a 'white' aperture always stays where placed --- it does not track and is never part of an aperture constellation group.
- A **red** aperture has the special property that it will only form a mask from a blob that is within 8 pixels of the center. This helps keep a nearby bright star from interfering with mask formation.
- Note: An aperture is never allowed to extend outside the image boundary. As a result, if an aperture is placed on a star that is close to the image edge and that star subsequently moves closer to the edge, tracking will be lost when the aperture bumps up against edge. In this case, use of a smaller aperture will allow tracking closer to the edge."

For a standard reduction, it should be sufficient to set a red aperture to the target, a yellow aperture to a tracking star (which is also the first comparison star) and again a red aperture to a second comparison star ([Figure 3.17](#)).

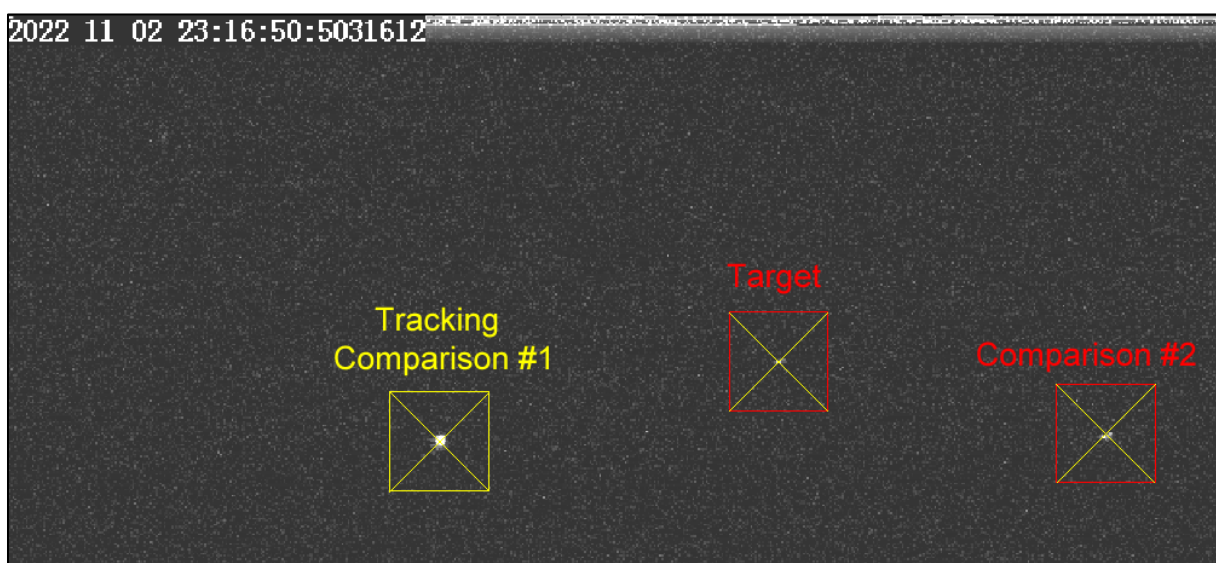


Figure 3.17. Aperture setting example.

The aperture details set can be viewed and changed via the "Examine/change aperture settings" button. It is very useful to save the aperture settings with "Save aperture group", PyMovie writes then two files: *savedApertures-xxx.p* and *savedFrameNumber-xxx.p* where xxx is the selected name of the aperture group. Via "Restore aperture group" the apertures can be recalled later. Occasionally, a saved aperture group could also be sent to a second reviewer or to the observer.

Mask threshold

In contrast to common photometry methods, including Tangra, PyMovie can work with adaptive masks. The basic concept is described in *PyMovie-doc.pdf* (included in the programme path):

- "The prime motivator that drove the development of this program was the belief that an aperture photometry program that could deal robustly and effectively with videos that have been affected by wind shake would be a useful tool. PyMovie uses the idea of forming a sampling mask from the image itself so as to get a sampling mask that adapts/conforms to the shape of a star image that has been distorted by wind shake. Such a mask minimizes the inclusion of background pixels. The expected benefit from this procedure is an increased SNR, particularly during the occultation as the intensity drops and the image gets smaller. This effect is useful even for videos that do not exhibit wind shake."

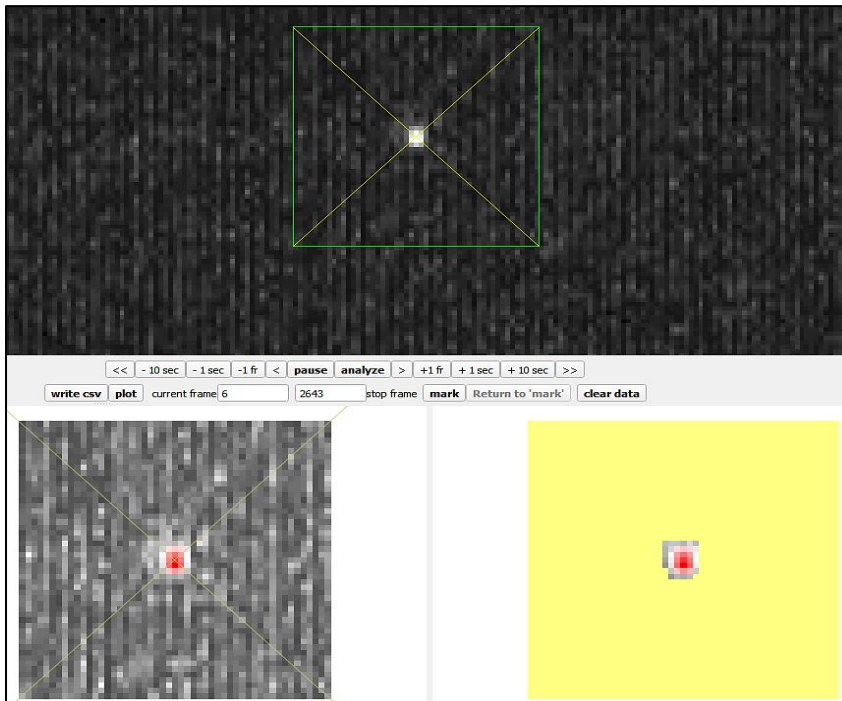


Figure 3.18. Example showing *Thumbnail Two* (bottom right) using a value of 14, which is the default (2 sigma) mask threshold. The green aperture indicates that it is connected to the threshold spinner.

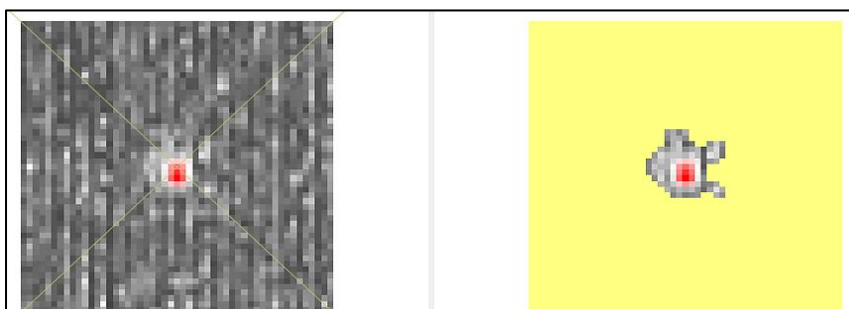


Figure 3.19. *Thumbnail Two* (right) after changing the mask threshold from 14 to 4.

The details are described in the context help getting by right clicking on “Set mask threshold (*mskth*) counts above background (*bkavg*)”, see [Figures 3.18](#) and [3.19](#) for an example:

- “If there is a currently 'green' aperture showing, its threshold value will be set to any new value from this spinner and *Thumbnail Two* in the lower right corner will update dynamically to show the effect of the change on the binary sample mask generation.

The mask threshold is always set as counts above average background. A good starting point for setting this value is to set it equal to the background noise (found in the column labeled *bkstd* in the text box) rounded up. The program tries to do this automatically so, in most cases, this value will already be preset. This is sometimes referred to as 'setting the threshold to 1 sigma'.

Note: *mskth* (mask threshold) and *bkavg* (background average) are column headings in the text box.”

In cases of critical reductions (maybe having bad SNRs, strong seeing effects, mechanical shaking) it often helps to vary the mask threshold of the target star.

Generating a lightcurve

This occurs by simply pressing the “analyze” button. The analysing process will need a while and can be interrupted (“pause”) and continued at any time.

To check if all goes right, one can press the “plot” button (also *during* the analysing process, without the need of interrupting before). Then, a composite lightcurve is plotted ([Figure 3.20](#)) as well as single lightcurves for all individual apertures. If something is wrong, after “clear data” a new analysing run is possible.

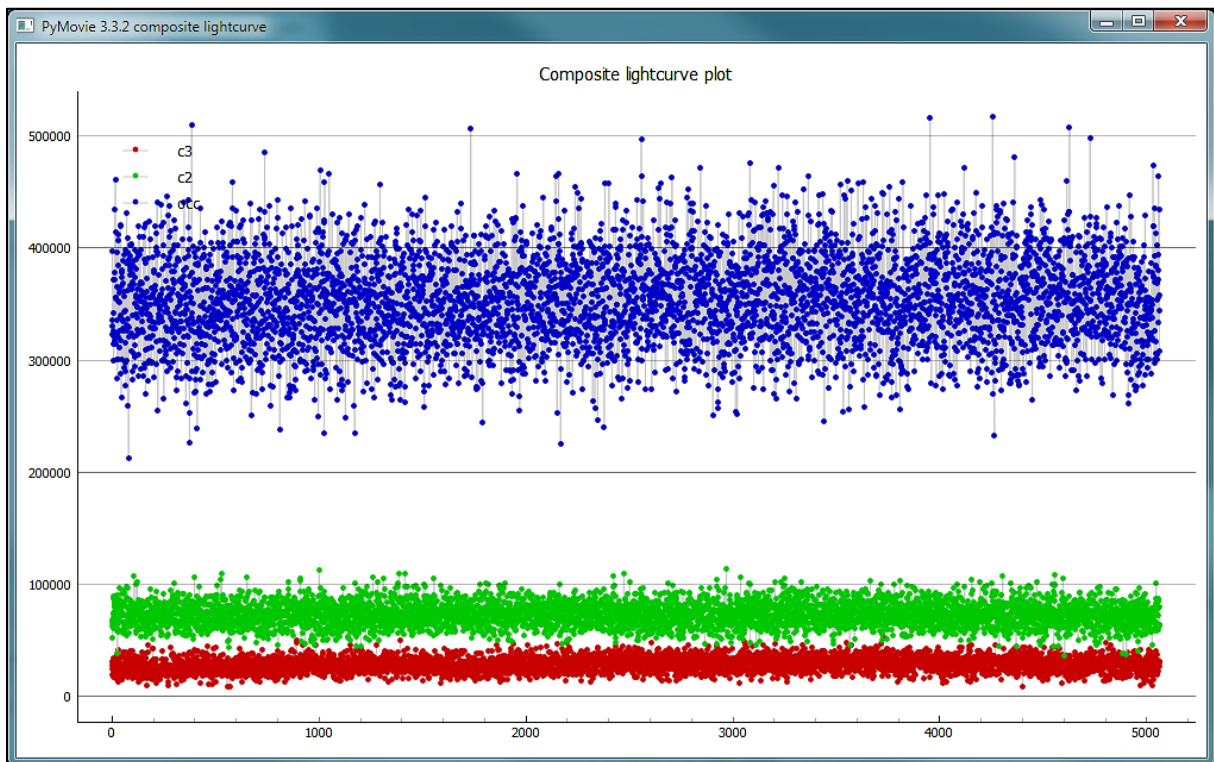


Figure 3.20. With PyMovie’s “plot” button generated composite lightcurve.

If the analysis is finished, before saving the result, the checkbox “*auto-run PyOTE*” should be checked. Then, with “*write CSV*”, the lightcurve will be written to the appropriate directory and PyOTE will automatically open and show the lightcurves.

PyMovie offers a wide range of additional options and tools that need to be studied and/or used if necessary. Only one example is given: The possibility to 3D-render the *Thumbnail One* image, for an example see [Figure 3.21](#). The feature is reached over *Misc/Show 3D thumbnail*.

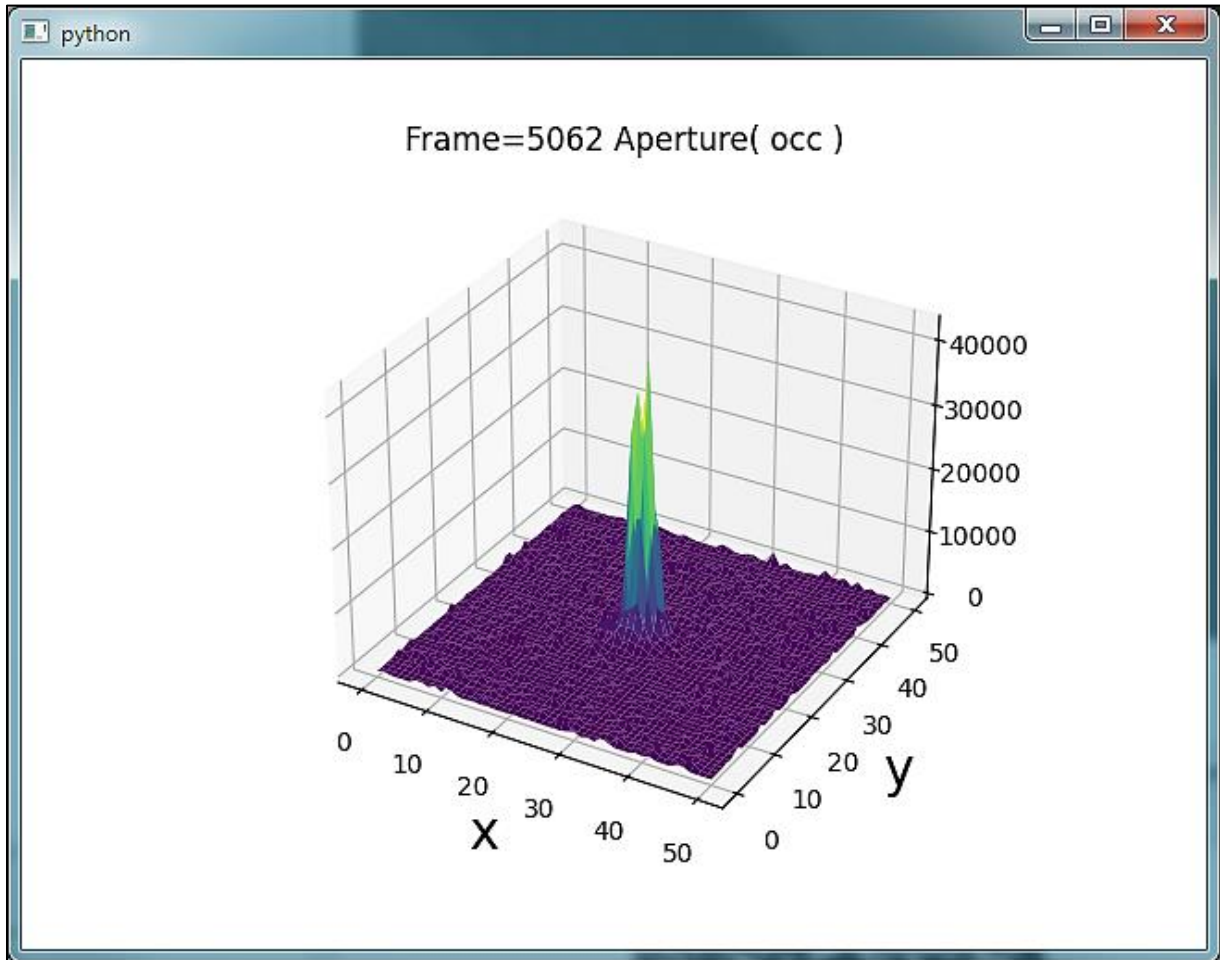


Figure 3.21. 3D-rendering of the *Thumbnail One* image (frame 5062 of the target aperture, named “occ”).

3.3 Lightcurve analysis issues

The lightcurve analysis (mainly to extract occultation times - but not only) is basing on the photometry results. Common software is AOTA (part of Occult4) and PyOTE (Figure 3.22). For various reasons (one of which is dealing with instrumental delays) it is best to use AOTA for Tangra photometry and PyOTE together with PyMovie, but with care and for comparison purposes PyOTE can read Tangra photometry CSV files just as well as AOTA can read PyMovie photometry.

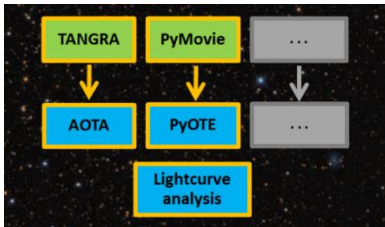


Figure 3.22. Common lightcurve analysis software.

When doing data reduction of occultation photometry results, there are many possible problems that can affect this - only some of them are listed below. It is not intended to describe the lightcurve analysis programmes itself in detail. For this, consult the relevant web resources and programme guides. In general, at least with complicated data reductions, it can be very useful to repeat the photometry with changed parameters and/or to use a different programme.

3.3.1 AOTA

AOTA as part of Occult4 is still the standard evaluation programme in Europe. One of its advantages is that, together with Tangra, it accurately handles the time delays of a wide range of cameras. A very detailed guide is part of the Occult4 help system. AOTA is logically structured, the problems occur mainly with "tab5" (Figure 3.23).

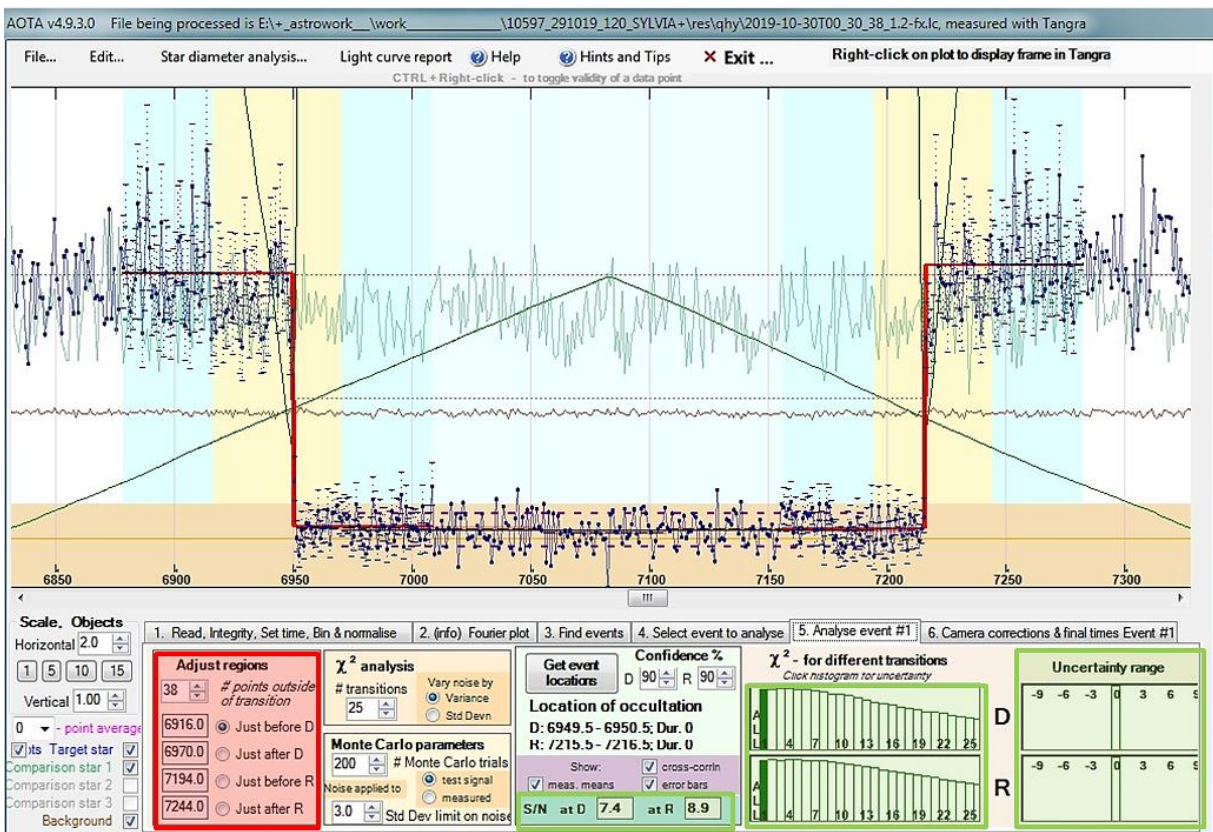


Figure 3.23. AOTA tab5, take care on the red and green marked areas.

[Figure 3.24](#) shows AOTA's tab5 automatic result. The bad things are marked with red arrows. After manual adjustments the result is improved, see [Figure 3.25](#). How to make the adjustments is part of the AOTA help:

AOTA tab5 „Adjust regions“: Guidance E. Frappa, Source: Occult4, Help: AOTA/Hints and Tips

- “In AOTA, you almost always have to review and **manually set the zones of transition (in yellow) in tab 5, "Adjust regions"**, with enough points on each side of the actual transitions, allowing AOTA to calculate the uncertainties based on the local noise of the curve. To set these zones, just click on the curve when you are in tab 5, then the corresponding points will fill the 4 fields in the "Adjust regions" window. The 2 yellow zones have to include points at full level and points at occultation level. The rule, most of the time, is that the calculated uncertainties (red lines) should never touch a yellow border. Don't be fooled by the words "just before" and "just after". They don't mean that you have to frame strictly the start and end of the transition. In this case, the result would be forced. On the contrary, make the yellow zones large enough (this can be limited sometimes at the occultation level when the event is short).
- When setting the zones of transition and **when the drop is not at the background**, don't choose the same point for the 2nd and 3rd points, this to prevent AOTA making the bottom of the fit on the background instead of on the occultation level. Shift the point by at least one value for very short events - and when you have a large event, ensure the blue zone in the middle to be large enough to allow a good average of the bottom level of the occultation.
- **The blue zone is controlled by the "# points outside of transition" in "Adjust regions"** and is used to measure locally the mean full and occultation levels. Use its extent intelligently according to the state of the light curve outside the event (avoid when possible unrepresentative levels such as gust of wind, outliers, etc).
- When you click on "get event locations", if the fit does not match the occultation (ingress, egress and occultation level) and the yellow zones are different than the ones you choose (assuming that you have set them correctly), **just move back and forth the "# points outside of transition"** value and everything should be back to normal.
- Always in tab 5, the histogram "chi2 - for different transitions" gives you the best transition for D and R. For that, click on the highest rectangle in the histogram. However, use **only transitions of type 1 or 2** - not more - unless you have a good reason to think that the transition is really gradual. Noise can often mimic a gradual transition and using such a fit (3 or more) can lead to times with small uncertainties where the result would require large ones because of the noisy event.
- Each click on the selected green rectangle in the chi2 histogram runs a Monte Carlo analysis, which allows you to test different solutions independently for D and R. The statistical nature of the analysis gives a range of different results, which is normal. **Try multiple clicks on the green rectangle** and, when possible, prefer the most symmetrical solution around the apparent transition.“

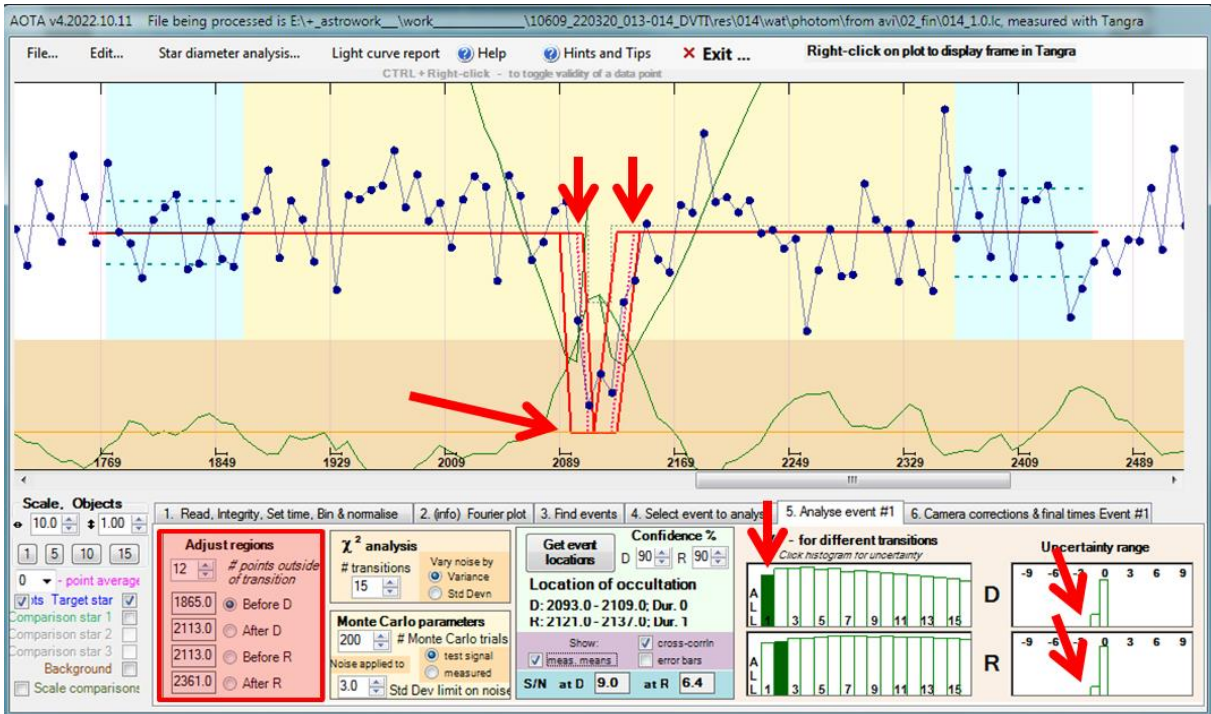


Figure 3.24. AOTA tab5 automatic result (follows after tab4, "Analyse #event").

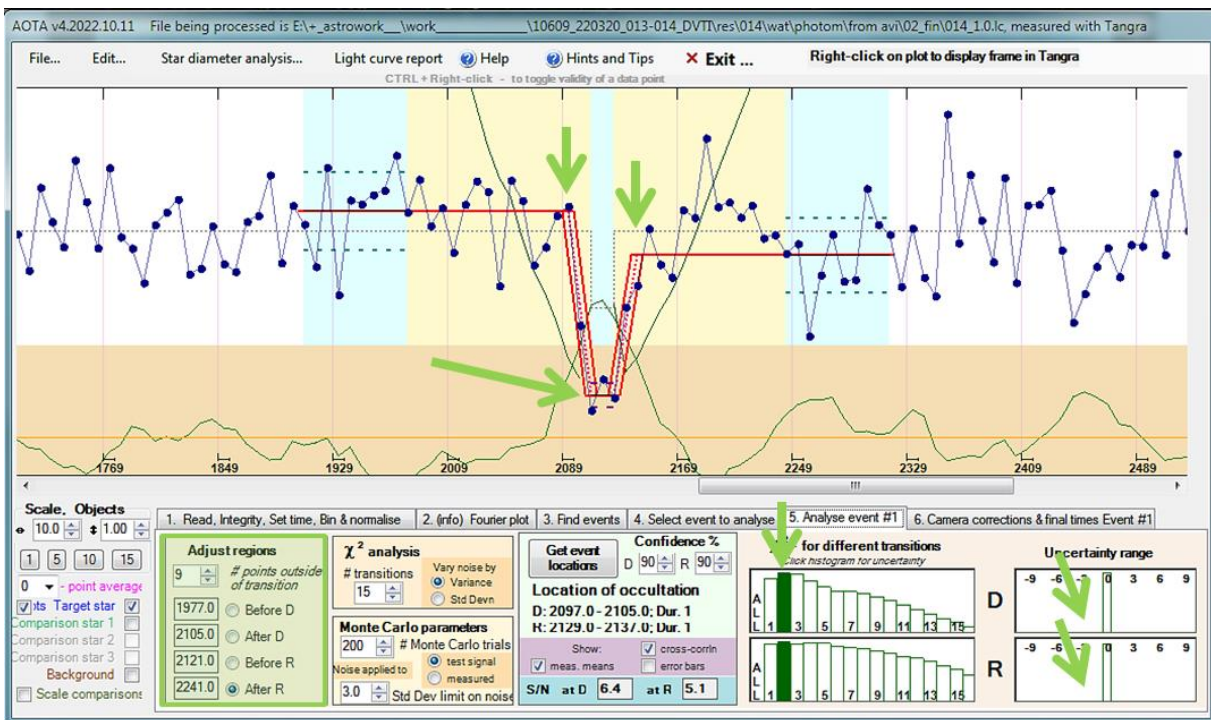


Figure 3.25. AOTA tab5 after "Adjust regions" done manually.

3.3.2 PyOTE

Note: In the following, some of the illustrations refer to PyOTE versions before version 5.0.7.

PyOTE is a Python-based programme for the photometry of occultation recording light curves. PyOTE can work independently and only reads CSV files, preferably from PyMovie. For some general notes, see the beginning of [Chapter 3.2.2](#). The PyOTE programme window either opens automatically after saving a CSV file in PyMovie, or a CSV file was directly read into PyOTE. [Figure 3.26](#) shows an example of the programme window with activated “Lightcurves” button. It is recommended to study the various possibilities of “Lightcurves” by using the big “Help” button at the top of “Lightcurves”.

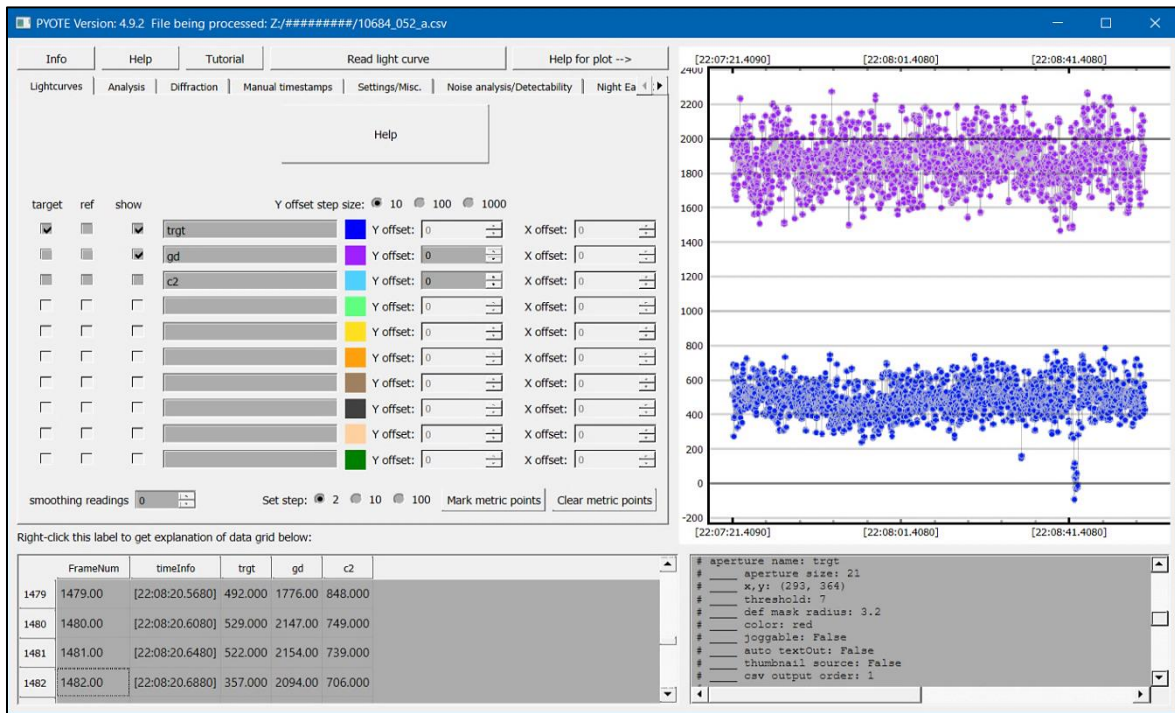


Figure 3.26. Example of the PyOTE GUI with activated “Lightcurves” button.

In particular, there are possibilities to smooth a reference curve and use it for normalisation, e.g. to take passing clouds into account ([Figure 3.27](#)).

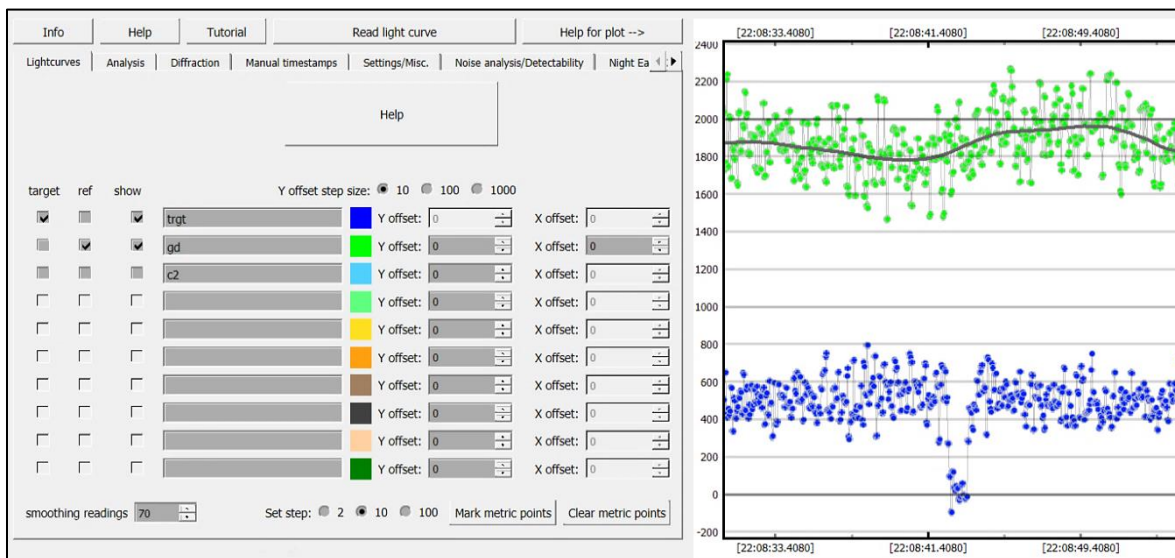


Figure 3.27. Smoothing the green reference lightcurve and using it to flatten the blue target lightcurve.

If for some reason the CSV file does not contain timestamps, but only frame numbers (perhaps PyMovie's OCR failed, or "flash timing" was used as a time reference), the "Manual timestamps" button activates the options for manual time entry (Figure 3.28).

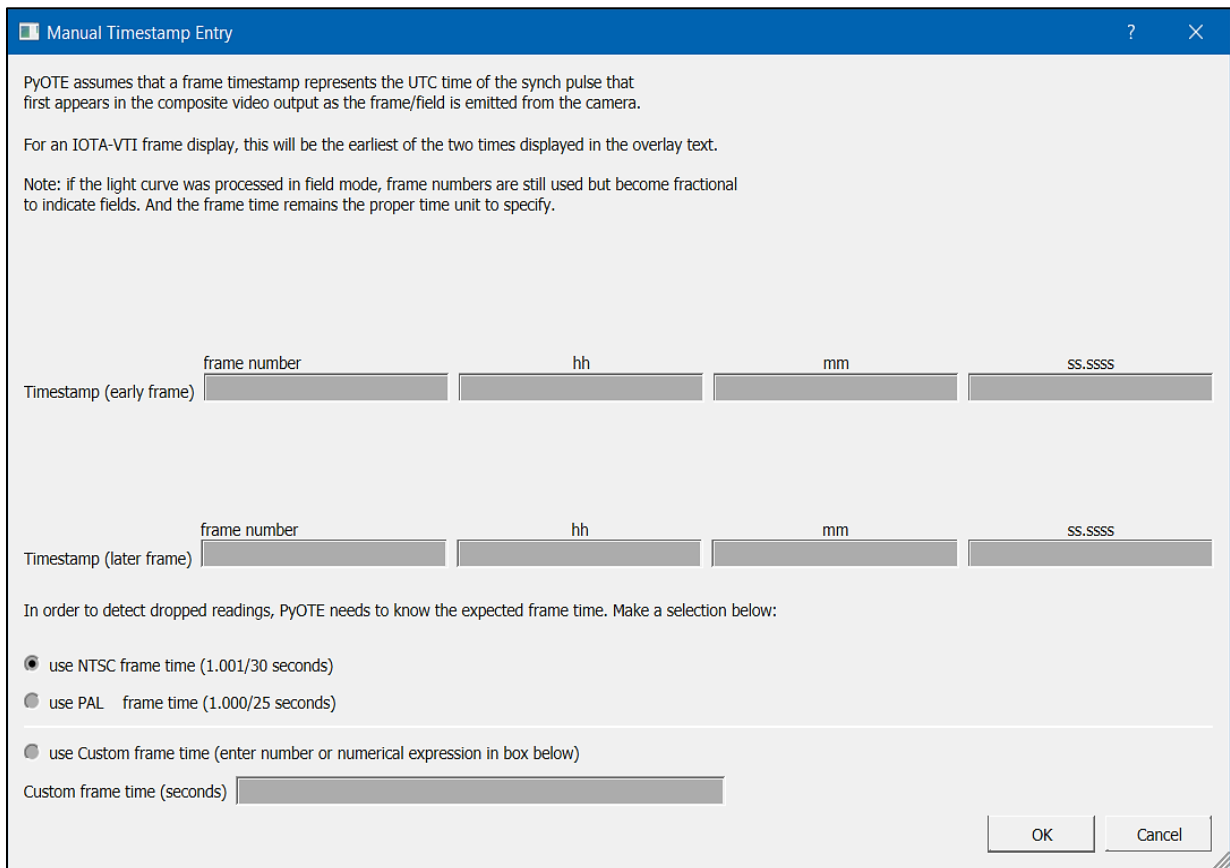


Figure 3.28. Manual timestamp entry options.

After displaying lightcurves, firstly one should have a look if there are timing errors like dropped frames or cadence errors. Such issues are marked with red and yellow vertical lines, as can be seen in Figure 3.7.

Starting with PyOTE 5.0., timing errors are also shown in the GUI log-window (low right corner) and are also written to the PyOTE logfile. See in the following an example from the logfile:

```

At reading 00006: time delta to next reading = 0.0101 : likely 1 dropped readings
At reading 00007: time delta to next reading = 0.0101 : likely 1 dropped readings
At reading 00014: time delta to next reading = 0.0101 : likely 1 dropped readings
At reading 05087: time delta to next reading = 0.0101 : likely 1 dropped readings
At reading 05337: time delta to next reading = 0.0101 : likely 1 dropped readings
At reading 05841: time delta to next reading = 0.0101 : likely 1 dropped readings
At reading 07189: time delta to next reading = 0.0152 : likely 2 dropped readings
At reading 08354: time delta to next reading = 0.0101 : likely 1 dropped readings

===== Total dropped readings..... 9
===== Num duplicated readings.... 0
===== Number of cadence errors... 8

timeDelta: 5.05930e-3 seconds per reading
timestamp error rate: 0.0841%
    
```

Compared to the past, the analysis of timing errors is also more detailed.

PyOTE's main functionality opens by pressing the *"SqWave model"* button ([Figure 3.29](#)).



Figure 3.29. *"SqWave model"* options .

The options are largely self-explanatory and arranged in logical order from top to bottom. The main functionalities are:

"Manual/automatic block integrate"

If an integrating camera and integration itself has been used, it is essential to block-integrate, otherwise PyOTE's results will be wrong. Normally PyOTE detects the block size automatically, but one can also block-integrate manually.

"Trim left/right"

This function can be used to exclude lightcurve areas outside of two specified points ([Figure 3.30](#)). It can be useful, for example, when there are strong lightcurve fluctuations (due to clouds, atmospheric scintillations) that cannot be handled by normalisation with a reference star.

If there are multiple drops, the ability can also be used to analyse a specific drop by excluding the others. However, the tool must be used with caution in order not to "artificially" increase the significance of potential events. The *"Start over"* button will remove any trim.

"Validate a potential single point event"

A false-positive test for a potential single point event can be performed here.

"Optional: enter the expected magDrop ..."

Also new in PyOTE 5.0.x is the possibility to evaluate measured and simulated drop sizes.

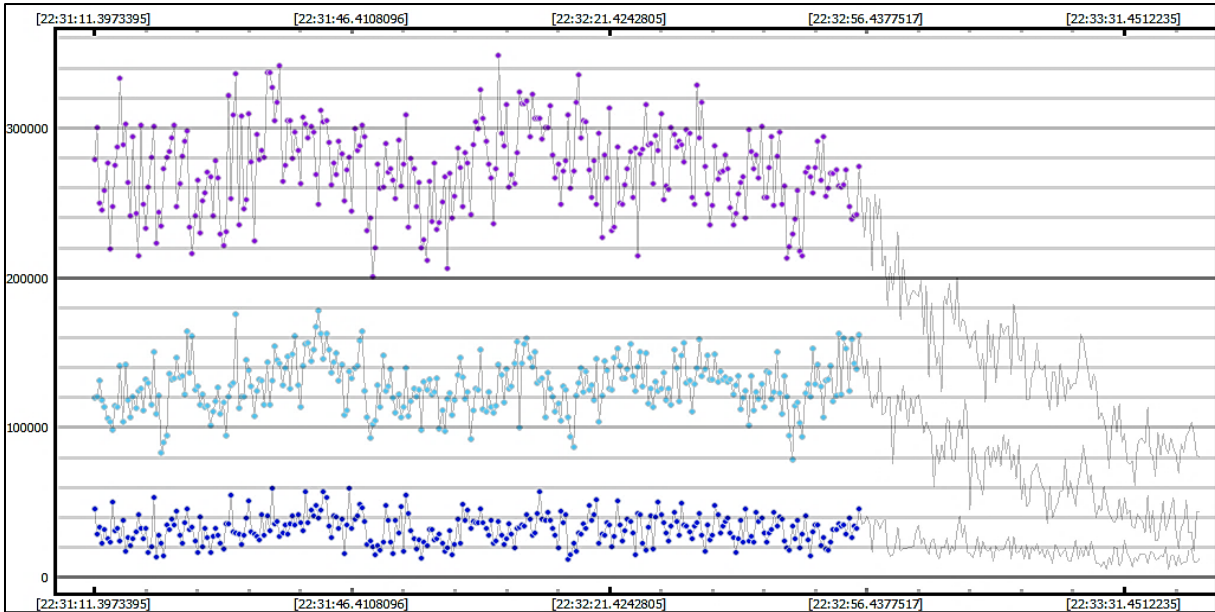


Figure 3.30. Lightcurve trimming, the greyed area is excluded.

Event identification

The first step is to tell PyOTE where the event search should take place. Mostly, entries for “*min/max event*” that is the minimal/maximal event duration (in readings), will work well. To check what PyOTE can find in general, the minimum event duration is 2 and the maximum can be greater than the maximum predicted event duration. The second option is to work with mouse-“*Mark D region/Mark R region*”.

By pressing the “*Find event, then ...*” button the analysis starts.

For demonstration purposes, the blue light curve from [Figure 3.30](#) was used to search (with “*min event*” = 2, “*max event*” = 20) for an “event”. [Figure 3.31](#) shows the result: PyOTE found an event, although in reality there was none.

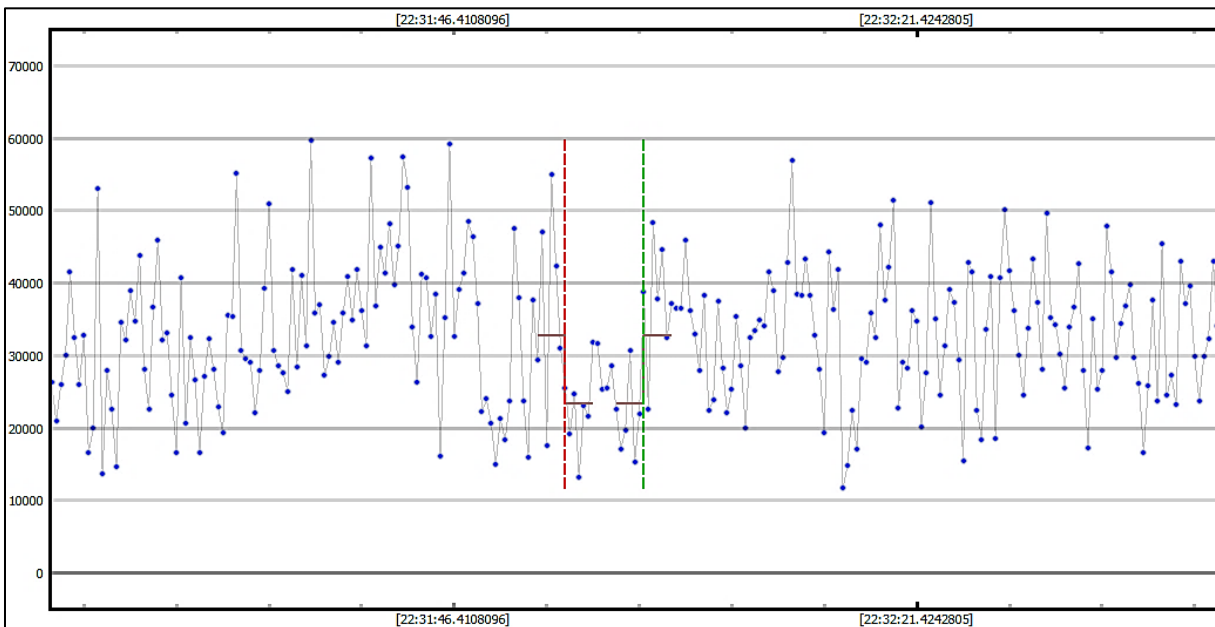


Figure 3.31. Result of an event search (with “*min event*” = 2, “*max event*” = 20) within the blue lightcurve of [Figure 3.30](#).

When PyOTE finds something, the button "... write report" becomes active. Referring to the above example, this results in [Figure 3.32](#).

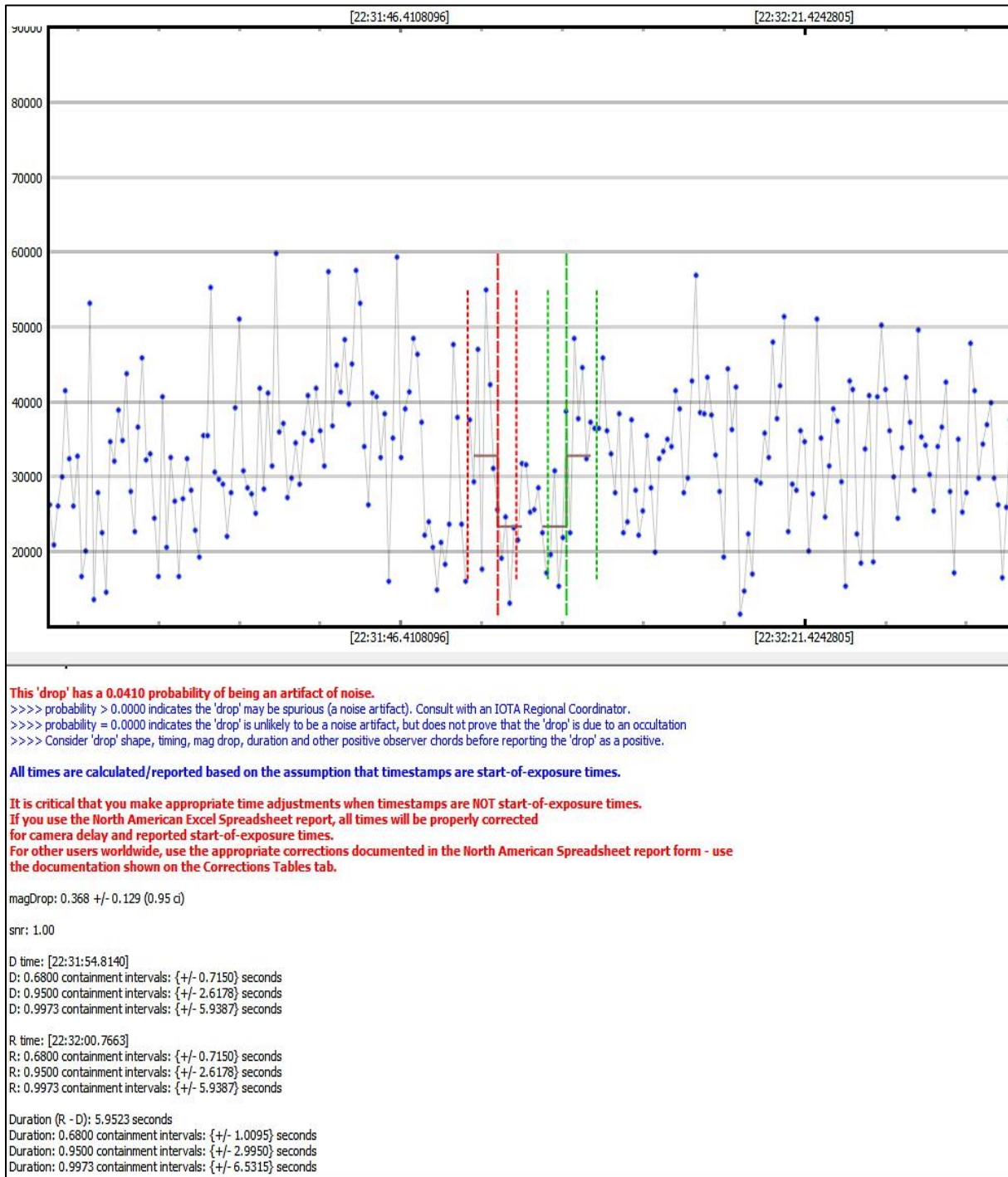


Figure 3.32. PyOTE analysis result of the “event” found according to [Figure 3.31](#).

The result demonstrates a main feature of PyOTE, the ability to check the overall probability of an event. As awaited, in the above case, we have to do with a false-positive event. This is also demonstrated with PyOTE’s correlated false-positive plot, shown in [Figure 3.33](#).

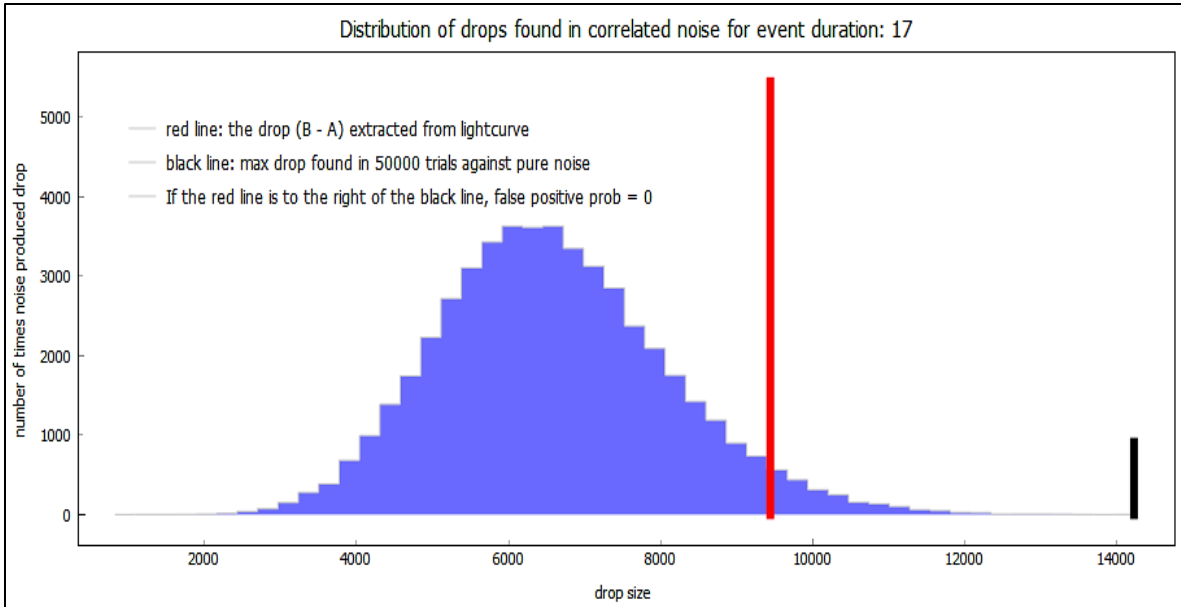


Figure 3.33. PyOTE’s false-positive plot of the above example (false-positive because the red line is left of the black one).

With the main button **“Noise analysis/Detectability”**, PyOTE can calculate the parameters to get a positive event (false-positive probability lower than 0). Doing this with the above example, one gets the following (Figure 3.34):

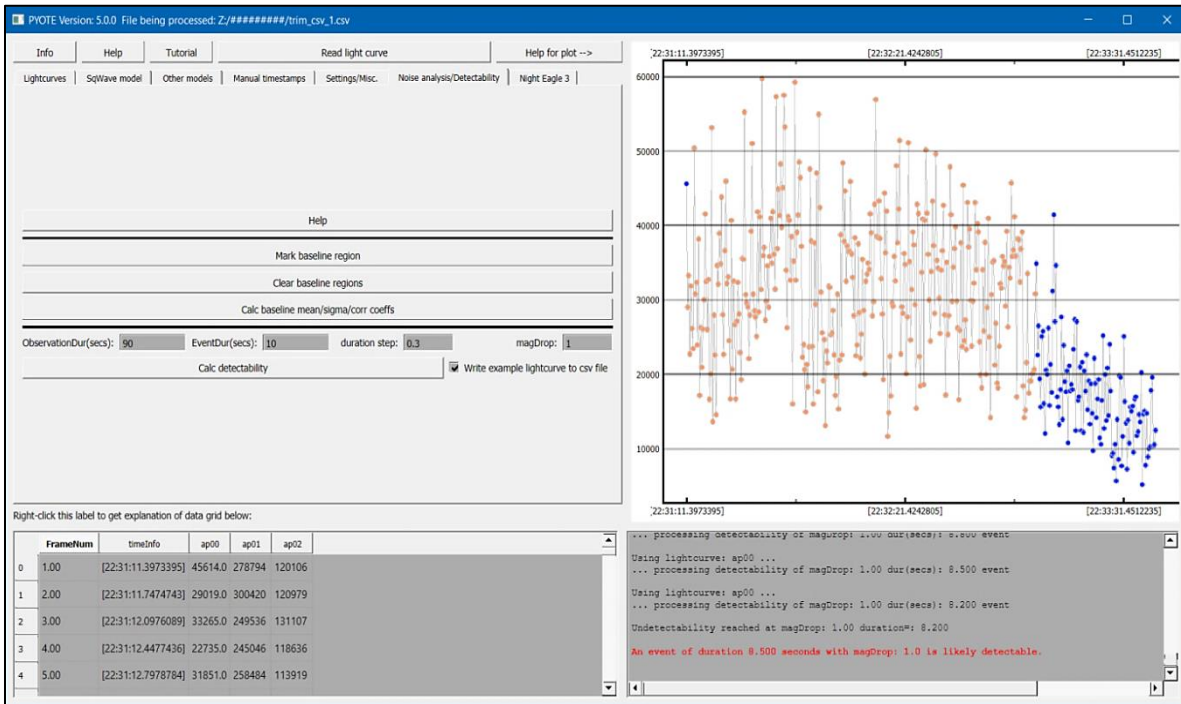


Figure 3.34. Using the PyOTE detectability tool with the example above. The baseline (brown) was calculated excluding the blue area. With the settings made (observation duration 90 s, magdrop 1), for this lightcurve one gets a duration of a positive event to be 8.5 s or more. All durations lower than 8.5 s would have the red line left of the black one (compare Figure 3.33). Calculating with a lower mag drop than 1, for a positive event the duration would exceed the 8.5 s. Calculating with the mag drop of 0.368 found with the pseudo “event” from Figure 3.32, we do not get a positive event at all.

The calculations with the detectability tool allow checking whether an event is a positive event in the trade-off between SNR, drop, drop duration and observation duration. The analysis results of PyOTE are automatically written in the form of various files to the folder in which the lightcurve CSV is located.

Like PyMovie, also PyOTE offers a wide range of additional options and tools that need to be studied and/or used if necessary.

As of PyOTE 5.0.x, it is now possible to work with models other than just square wave modeling. According to *pyote-info.pdf*, located in the programme path, these are:

“Added a comprehensive set of lightcurve models together with tools to help automate the fitting of the new models to observation data. Models included:

- Diffraction (including central spot for low rho events) using physical optics
- Disk on disk (geometrical optics) for large stars
- Edge on disk (geometrical optics) for large stars and limb angles on asteroid”

These options are activated with the **“Other models”** button. From there, a very detailed documentation (*model-help.pdf*, located in the programme path) is reachable via the **“Help”** button. In addition, PyOTE provides corresponding CSV files with model examples (folder located in the Documents folder). For an example regarding see [Figure 3.35](#).

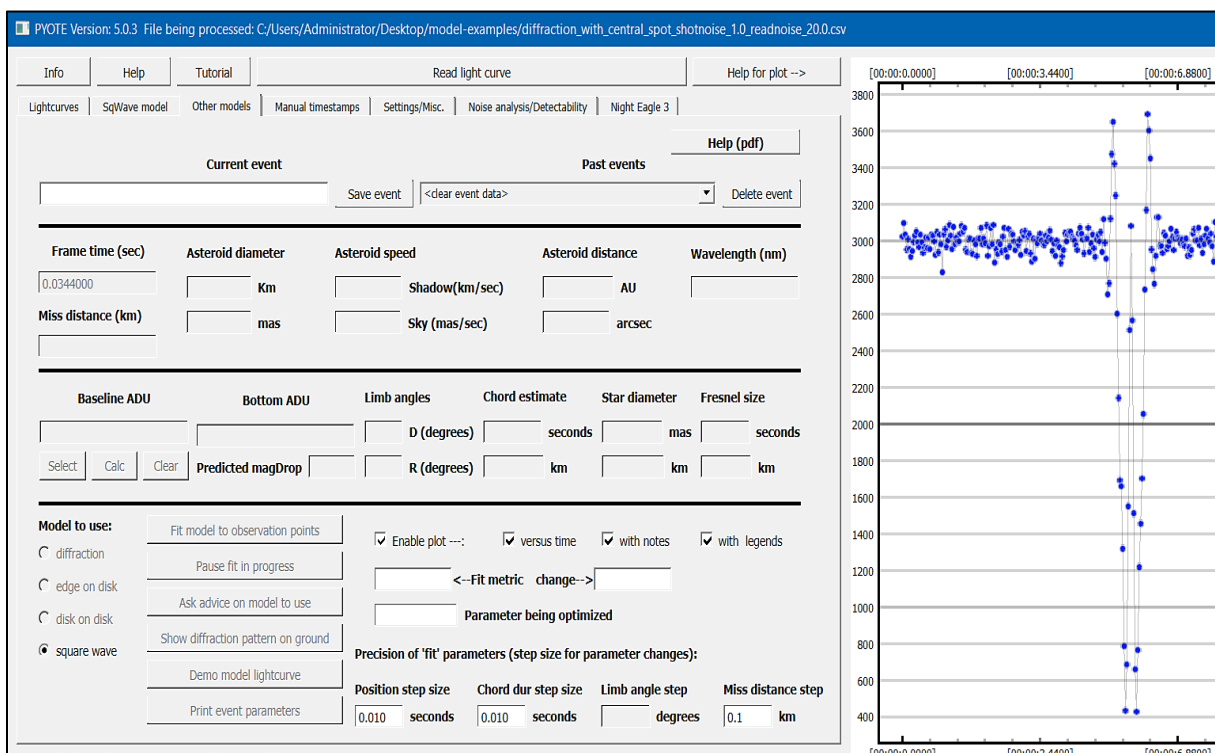


Figure 3.35. PyOTE “Other models” tab, one of the provided demonstration files is loaded

Another new feature (starting with PyOTE 5.0.5) is the creation of occultation light curves in the VizieR required format (AOTA already has this option) for export to Dave Herald. The lightcurves can be seen from Occult4/Asteroid Observations/Light curves. They are exported to VizieR by D. Herald. [Figure 3.36](#) shows PyOTE’s “VizieR export” tab and a lightcurve example.

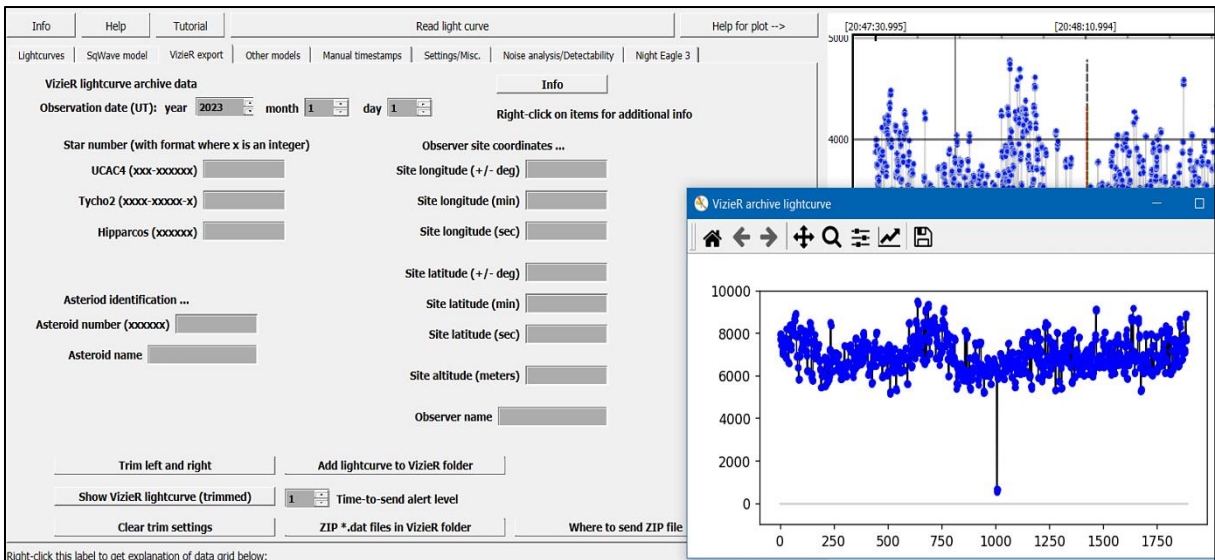


Figure 3.36. PyOTE “VizieR export” options.

3.3.3 Single point event analysis example

As described in [Chapter 1.2](#), SODIS also deals with observations that are/will be classified as "uncertain". One such event category is single point events. In this section, an example is presented showing the lightcurve analysis with AOTA as well as with PyOTE.

Lightcurve

[Figure 3.37](#) shows the Tangra lightcurve of a WAT910HX recording with 4 frames integrated. There is a clear one-point drop, but it could not be assigned to a real occultation event. However, it is well suited as a model for demonstration purposes.

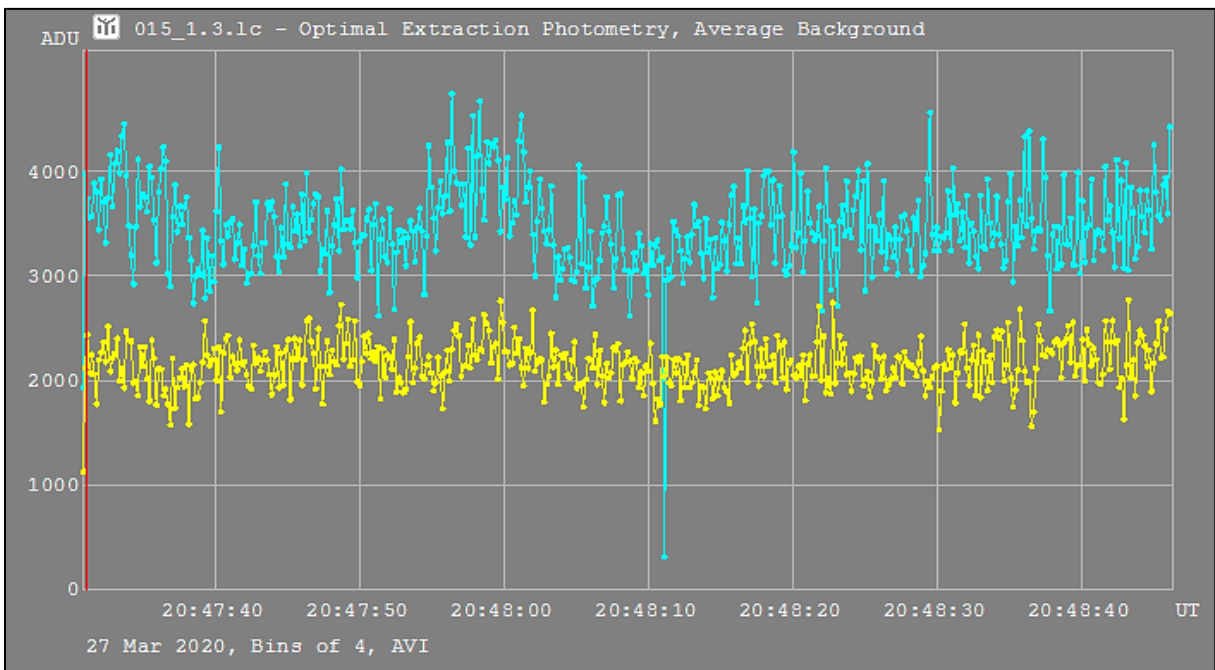


Figure 3.37. Tangra lightcurve showing a single point drop event.

AOTA

AOTA’s tab5 and tab6 results are presented in [Figures 3.38](#) and [3.39](#).

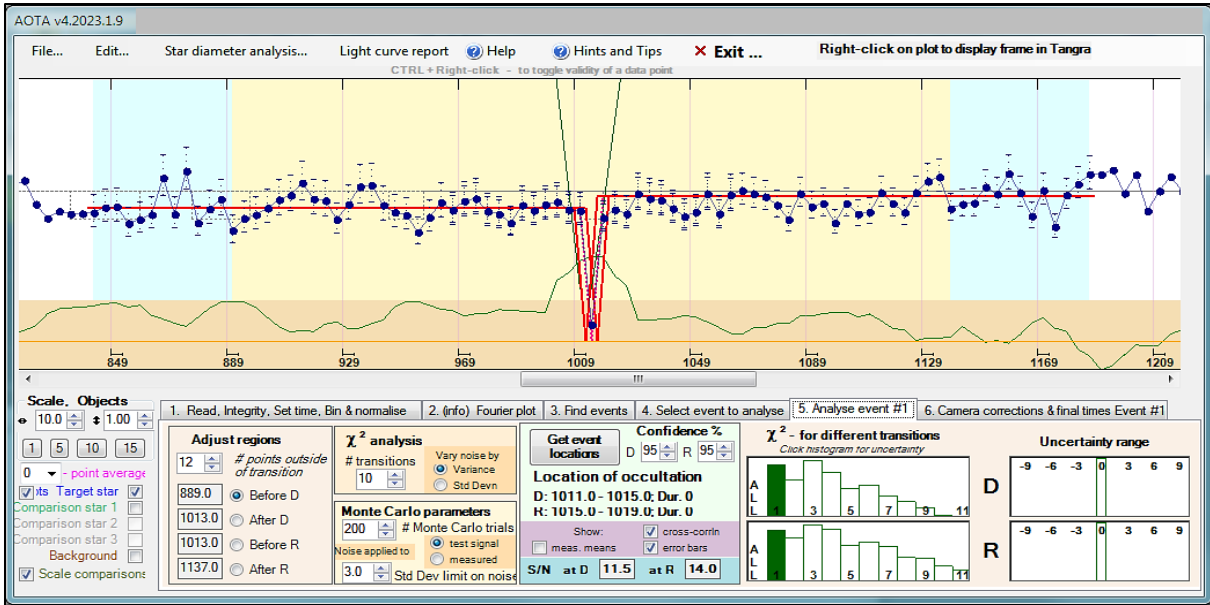


Figure 3.38. AOTA tab5 result.

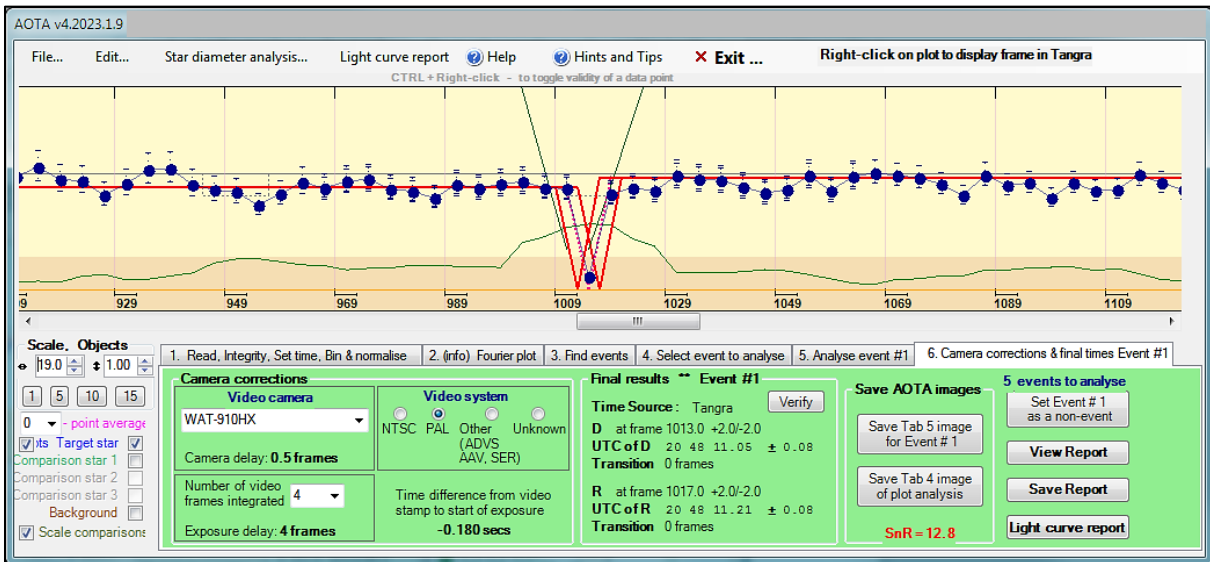


Figure 3.39. AOTA tab6 result.

PyOTE

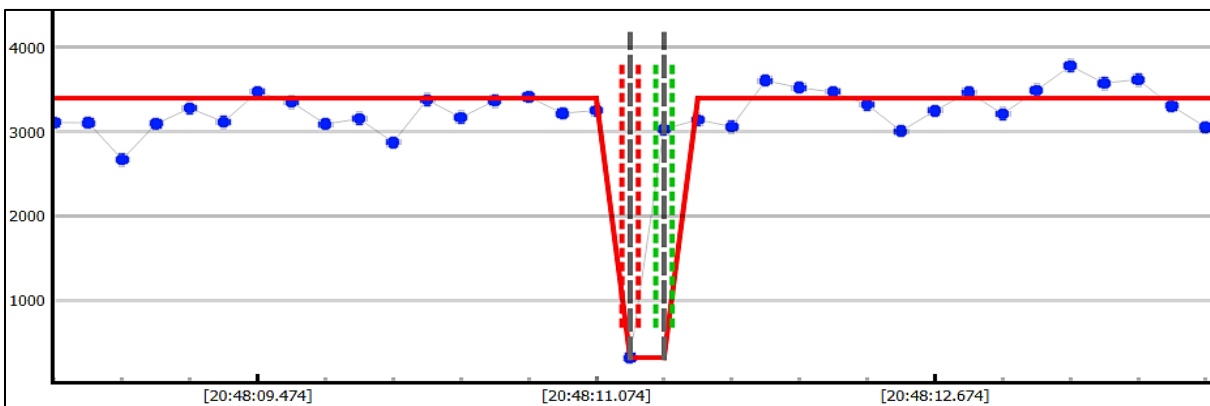


Figure 3.40. PyOTE result.

[Figure 3.40](#) shows the result of the reduction with PyOTE. The false-positive test was negative.

A comparison AOTA/PyOTE shows very similar results:

	Tangra > AOTA	Tangra > PyOTE
D:	20:48:11.05 +/- 0.08	20:48:11.054 +/- 0.039
R:	20:48:11.21 +/- 0.08	20:48:11.214 +/- 0.039
Dur.:	0.16 s	0.16 s
Drop:	2.50 mag	2.56 mag
SNR:	12.8	9.51

Note: The intent here was only to show the reduction of a single point with common software. There are serious concerns with such events, see Chapter 1 / [Occult4/SODIS classification of observations](#).

4 Links

IOTA	https://occultations.org/
IOTA mailing list	https://groups.io/g/IOTAoccultations
IOTA/ES	https://iota-es.de/index.html
NASA PDS SBN Occ.	https://sbn.psi.edu/pds/resource/occ.html
MPC	https://www.minorplanetcenter.net/
VizieR occ. lightcuves	https://vizier.cds.unistra.fr/viz-bin/VizieR-3?-source=B/occ&-out.max=50&-out.form=HTML%20Table&-out.add=r&-out.add=RAJ,DEJ&-sort=r&-oc.form=sexa
Planoccult	https://lists.vvs.be/postorius/lists/planoccult.ls.vvs.be/
Occult Watcher (OW)	https://www.occultwatcher.net/
OW add-ins	https://www.occultwatcher.net/MoreAddins.html
OW Occult tools	http://www.hristopavlov.net/OccultWatcher/OccultW.OccultTools.zip
Occult Watcher Cloud	https://cloud.occultwatcher.net/
OWC mailing list	https://groups.io/g/OWCloud
SODIS	https://sodis.iota-es.de/
SODIS forum	https://forum.iota-es.de/index.php
SODIS docu	https://www.iota-es.de/sodis/sodis_docu.html
CORA	https://astro.kretlow.de/cora/
SORA	https://sora.readthedocs.io/index.html
Euraster	http://www.euraster.net/results/index.html
Occultation portal	https://occultation.tug.tubitak.gov.tr/about/
Tangra	http://www.hristopavlov.net/Tangra/Tangra.html http://www.hristopavlov.net/Tangra3/
Tangra timestamps	https://iota-es.de/SC-Timestamps_01.pdf
IOTA/ES Tangra worksh.	tbd
PyMovie/PyOTE	http://occultations.org/observing/software/pymovie/
PyM/PyO inst. guide	https://occultations.org/sw/pymovie/WinPyMoviePyOTE-Install-2022-9-16.zip
PyMovie repository	https://github.com/bob-anderson-ok/pymovie/tags

PyOTE repository	https://github.com/bob-anderson-ok/py-ote/tags
PyMovie inst. source	https://pypi.org/project/pymovie/
PyOTE inst. source	https://pypi.org/project/pyote/
Occult/AOTA	http://www.lunar-occultations.com/iota/occult4.htm
SharpCap	http://www.sharpcap.co.uk/
SharpCap forum	https://forums.sharpcap.co.uk/
ADV format	https://forums.sharpcap.co.uk/viewtopic.php?f=8&t=2237
SER format issues	https://forums.sharpcap.co.uk/viewtopic.php?f=8&t=2237 https://www.iota-es.de/JOA/JOA2020_3.pdf
QHY174GPS	https://www.qhyccd.com/qhy174gps-imx174-scientific-cooled-camera/
QHY174GPS worksh.	https://www.iota-es.de/qhy174gps_workshop.html
QHY174GPS FW updt.	https://esop39.iota-es.de/lections/ESOP39_C.Weber_QHY-FW.pdf
DVTI	https://dvticam.com/product
DVTI mailing list	https://groups.io/g/d-vti-cam
DVTI tests	https://esop39.iota-es.de/lections/ESOP39_C.Weber_DVTI.pdf
G. Dangl tests	http://www.dangl.at/menu_hhe.htm
WATEC	https://www.watec.co.jp/English/e_mono.html
Meinberg NTP	https://www.meinberg.de/german/sw/ntp.htm

5 Appendix

5.1 Structure and format of the Occult4 asteroid observation XML file

```

<Observations>
  <FileVersion>file version number</FileVersion>
  - <Event>
    <Date> year| month| day| hour</Date>
    - <Details>
      <Star> Catalogue| number| Gaia version|Gaia id| RA2000 (hh.hhhhhhhhh)| Dec2000 (+/-dd.dddddddd)|RA uncertainty (mas)
        |Dec uncertainty (mas)|Stellar diameter (mas)|IssuesFlag| RA Apparent (hh.hhhhhhh)| Dec Apparent(+/-dd.ddddddd)
        |Mb|Mg|Mr| EPIC ID</Star>
      <StarIssues>Reliability|Gaia Duplicated Source flag|No Proper Motion flag|Proper motion using UCAC4|Double star solution - star
        brightness ratio|Uncertainty in the star brightness ratio, in percent|Double star solution RA offset (mas)| Double star solution
        Dec offset (mas)|Standard Deviation RA offset (mas)| Standard Devaition Dec offset (mas)</StarIssues>
      <Asteroid> Number| Name| dX| dY| d2X| d2Y d3X| d3Y| Parallax| dParallax| Nominal mean diameter (km)|Uncertainty in mean
        diameter (km)| Mv</Asteroid>
    - <EventFits>
      <SolveFlags>X| Y| Major Axis| Minor Axis| PA Major Axis| Circular solution| Include Miss events| Separation of 2nd
        star/asteroid moon| PA of 2nd star/asteroid moon</SolveFlags>
      <EllipticFit>X| Y| Major axis| Minor Axis| PA Major Axis| Fit quality| Used Assumed Diameter| Flag for future review|Center of
        Mass X| Center of Mass Y</EllipticFit>
      <EllipseUncertainty>Sdev_X| Sdev_Y| SdevMajor| SdevMinor| SdevPA</EllipseUncertainty>
    - <ShapeModelFit>
      <Fit>Source| ID| SurfaceDia/VolumeDia ratio| Fit quality| Phase correction| Volume Dia Min| Volume Dia Max|
        Version</Fit>
      .....
    </ShapeModelFit>
    - <SatelliteFit>
      <Satellite>IAU designation|SatdX|SatdY|Satd2X|Satd2Y|Separation|J2000 Position Angle|Uncertainty in
        separation|Uncertainty in Position angle| Major axis| Minor Axis| PA Major Axis| Fit quality</Satellite>
      ....
    </SatelliteFit>
    - <DoubleStar>
      <Solution>PA| Separation| sdev_PA| Sdev_Separation| Centre_X| Centre_Y| Offset_X| Offset_Y| Solution number</Solution>
      ...{either 1| 2 or 4 lines| depending on the nature of the solution}
    </DoubleStar>
    </EventFits>
  - <Astrometry>
    <ReferenceTime>year| month| day|Reference hour|Uncertainty</ReferenceTime>
    <MainBody>IAU designation|GeocentricX| GeocentricY|dRACosDec|dDec|UncerRA|UncertDec| Position centered on shape
      model|number of chords used|Position for an unseen primary of a binary asteroid|Fit code|Adjustment to the across path
      uncertainty|adjustment to the along path uncertainty|Maximum +ve Hit chord distance|Maximum -ve chord
      distance|Minimum +ve Miss chord distance|Minimum -ve chord distance</MainBody>
    <MainAtConjunction>IAU designation|GeocentricX at conjunction|GeocentricY at conjunction|Position for an unseen primary of a
      binary asteroid</MainAtConjunction>
    - <SatelliteBodies>
      <Secondary>IAU designation|GeocentricX| GeocentricY|PA_2000|dRACosDec|dDec|UncerRA|UncertDec|number of chords
        used</Secondary>
      <SecondaryAtConjunction>IAU designation|MiriadeMotions|GeocentricX| GeocentricY|Year|Month| Day of
        conjunction|Sdev_day|Sdev_AloneTrack|Separation|Sdev_Separation|PAatConjuncton</SecondaryAtConjunction>
      ...} ...}
    </SatelliteBodies>
    <MPC>Date of publication|Circular number</MPC>
  </Astrometry>
</Details>
- <Observations>
  <Prediction>Seq Num|Longitude| Latitude| hr| min| sec|Event comments</Prediction>
  - <Observer>
    <ID>Seq Num| Observer1| Observer2| MoreThan2Observers| NearLocation| State/country| Longitude| Latitude| Alt| Datum|
      TelescopeAperture| TelescopeType| Observing method| Time Source</ID>
    <Conditions>Stability| Transparency| SN| Time Adjustment| Comment</Conditions>
    <D>hh mm ss.ss| eventCode| Accuracy| PEqn| Weight| PlotCode</D>
    <R>hh mm ss.ss| eventCode| Accuracy| PEqn| Weight| PlotCode</R>
  </Observer>
  ...
</Observations>
<Added> yyyy|m|d</Added>
<LastEdited>yyyy|m|d</LastEdited>
</Event>
</Observations>

```

Figure 5.1. Structure of the Occult4 asteroid observation XML file (shortened, from Occult4 help: File formats/Asteroids/Observations XML format, Occult4 v. 4.2023.1.9).

The Occult4 asteroid observation format is described under Occult4 help: File formats/Asteroids/Observations XML format and is reproduced in the following (Occult4 v. 4.2023.1.9)

“Format for Asteroid Occultation Observations

Version 2.7+

XML format

Change log

- V1.0 - Added Hourly rate of change of parallax (dParallax) to <Asteroid>. Changed file name to Asteroid~Observations.xml. Introduced Version number as a field in the file
- V1.1- Added <MainAtConjunction> and <SecondaryAtConjunction>
- V2.0 - multiple changes in the <star> line and <astrometry> lines. See Revision details for v4.10.0.0 of 22 March 2020
- V2.1 - added a field in the 'Position for an unseen primary of a binary asteroid' to <MainBody>
- V2.2 - added diameter uncertainties to <asteroid>
- V2.3 - To <Astrometry><MainBody> added fields for 'Fit Code', adjustments to along and across path uncertainty (x2) and Maximum/Minimum chord distances (x4). In <Satellite>, corrected the of the units for the rates of motions
- V2.4 - Added new line <StarIssues> to include matters relating to the reliability of the Gaia star position. (RUWE, DuplicateSource flag, lack of proper motion, and where UCAC4 has been used to create a proper motion for the Gaia position Expanded the <Prediction> line to add a field for Fee text. In <EllipticFit> Added new field for 'Future Review'.
- V2.5 - Added offset of the Center of Mass from the Center of Figure fit. - at end of the <EllipticFit> line.
 - - Added a new event code 'N' for events involving a ring - in Observations><Observer><D>, and ...<R> (July 2021)
 - - Added a new telescope type - eVscope
- V2.6 - Added offsets from the star position to the position of the star used for the solution, plus ratio of component brightness, in <Star><StarIssues>(April 2022)
 - - Expanded the list of fit options for shape models, to include 'Not constrained'.
- V2.7 - Added a new event code 'n' for non-detection of events involving a ring - in Observations><Observer><D>, and ...<R> . Also revised the definitions of M and m to replace all references to 'Miss' with 'non-detection' (October 2022)

The structure of the xml file is as follows (for a shortened form see [Figure 5.1](#)):

```

<Observations>
  <FileVersion>file version number</FileVersion>
  <Event>
    <Date> year/ month/ day/ hour</Date>
    <Details>
      <Star> Catalogue/ number/ Gaia version/Gaia id/ RA2000 (hh.hhhhhhhhh)/ Dec2000
      (±dd.dddddddd)/RA uncertainty (mas)/Dec uncertainty (mas)/Stellar diameter (mas)/IssuesFlag/ RA
      Apparent (hh.hhhhhhh)/ Dec Apparent(±dd.dddddd)/Mb/Mg/Mr/ EPIC ID</Star>

      <StarIssues>Reliability/Gaia Duplicated Source flag/No Proper Motion flag/Proper motion using
      UCAC4/Double star solution - star brightness ratio/Uncertainty in the star brightness ratio, in
      percent/Double star solution RA offset (mas)/ Double star solution Dec offset (mas)/Standard Deviation RA
      offset (mas)/ Standard Devaiton Dec offset (mas)</StarIssues>
      <Asteroid> Number/ Name/ dX/ dY/ d2X/ d2Y d3X/ d3Y/ Parallax/ dParallax/ Nominal mean diameter
      (km)/Uncertainty in mean diameter (km)/ Mv</Asteroid>
      <EventFits>
        <SolveFlags>X/ Y/ Major Axis/ Minor Axis/ PA Major Axis/ Circular solution/ Include Miss events/
        Separation of 2nd star/asteroid moon/ PA of 2nd star/asteroid moon</SolveFlags>
        <EllipticFit>X/ Y/ Major axis/ Minor Axis/ PA Major Axis/ Fit quality/ Used Assumed Diameter/
        Flag for future review/Center of Mass X/ Center of Mass Y</EllipticFit>
        <EllipseUncertainty>Sdev_X/ Sdev_Y/ SdevMajor/ SdevMinor/ SdevPA</EllipseUncertainty>
        <ShapeModelFit>
          <Fit>Source/ ID/ SurfaceDia/VolumeDia ratio/ Fit quality/ Phase correction/ Volume Dia Min/
          Volume Dia Max/ Version</Fit>
          ....
        </ShapeModelFit>
        <SatelliteFit>
          <Satellite>IAU designation/SatdX/SatdY/Satd2X/Satd2Y/Separation/J2000 Position
          Angle/Uncertainty in separation/Uncertainty in Position angle/ Major axis/ Minor Axis/ PA Major Axis/ Fit
          quality</Satellite>
          ....
        </SatelliteFit>
        <DoubleStar>
          <Solution>PA/ Separation/ sdev_PA/ Sdev_Separation/ Centre_X/ Centre_Y/ Offset_X/ Offset_Y/
          Solution number</Solution>
          ...[either 1/ 2 or 4 lines/ depending on the nature of the solution]
        </DoubleStar>
      </EventFits>
    <Astrometry>
      <ReferenceTime>year/ month/ day/Reference hour/Uncertainty</ReferenceTime>
      <MainBody>IAU designation/GeocentricX/ GeocentricY/dRACosDec/dDec/UncertRA/UncertDec/
      Position centered on shape model/number of chords used/Position for an unseen primary of a binary
      asteroid/Fit code/Adustment to the across path uncertainty/adjustment to the along path
      uncertainty/Maximum + 've Hit chord distance/Maximum - 've chord distance/Minimum + 've Miss chord
      distance/Minimum - 've chord distance</MainBody>
      <MainAtConjunction>IAU designation/GeocentricX at conjunction/GeocentricY at
      conjunction/Position for an unseen primary of a binary asteroid</MainAtConjunction>
      <SatelliteBodies>
        <Secondary>IAU designation/GeocentricX/
        GeocentricY/PA_2000/dRACosDec/dDec/UncertRA/UncertDec/number of chords used</Secondary>
        <SecondaryAtConjunction>IAU designation/MiriadeMotions/GeocentricX/
        GeocentricY/Year/Month/ Day of
        conjunction/Sdev_day/Sdev_AlongTrack/Separation/Sdev_Separation/PAatConjuncton</SecondaryAtConjun
        ction>
        ...}
        ...}
      </SatelliteBodies>
    <MPC>Date of publication/Circular number</MPC>
  
```

```

    </Astrometry>
  </Details>
<Observations>
  <Prediction>Seq Num|Longitude| Latitude| hr| min| sec|Event comments</Prediction>
  <Observer>
    <ID>Seq Num| Observer1| Observer2| MoreThan2Observers| NearLocation| State/country|
Longitude| Latitude| Alt| Datum| TelescopeAperture| TelescopeType| Observing method| Time Source</ID>
    <Conditions>Stability| Transparency| SN| Time Adjustment| Comment</Conditions>
    <D>hh mm ss.ss| eventCode| Accuracy| PEqn| Weight| PlotCode</D>
    <R>hh mm ss.ss| eventCode| Accuracy| PEqn| Weight| PlotCode</R>
  </Observer>
  ...
</Observations>
<Added> yyyy/m/d</Added>
<LastEdited>yyyy/m/d</LastEdited>
</Event>
</Observations>

```

The tag <Observations> delimits the XML file.

The tag <FileVersion> specifies a version number for the file format. The number is a decimal number, and is used to identify the need to upgrade either the file, or the version of Occult.

The tag <Event> delimits the data for an event. The whole file will be read into memory, but only data within an event will be decoded (when required).

Within an event, the tags <ShapeModelFit>, <DoubleStar> and <BinaryAsteroid> will only be present when appropriate, as will three items under <Astrometry>

Within a data element, individual items are stored as pipe-separated-values. This allows commas to be used in several fields.

IMPORTANT. None of the data items have been corrected for the Gaia DR2 Frame Rotation error. This correction is only applied when generating astrometric outputs.“

Tag	Data items
Date	<p>Date of the event The year, month, and day of the event, and the hour (to 0.1 hrs) close to the observed event times. If observations extend across different days, specify the earlier day, with times going above 24hrs as required.</p>
Star	<p>Details of the star</p> <ul style="list-style-type: none"> • Catalogue - the catalogue identifier. The identifiers used are: HIP (Hipparcos), Tycho2 (or TYC), UCAC4, USNO-B1, NOMAD and G-coords • Number - the number in the catalogue • Gaia version - The source of the star position. 0 = Hipparcos2, 1 = Gaia DR1, 2 = Gaia DR2, 3 = Gaia EDR3, -1 = not specified • Gaia id - the 18-digit Gaia id in the relevant Gaia version • Right Ascension (hh.hhhhhhhhh - the RA of the star. GCRS coordinates. (That is, coordinates referred to the ICRS reference frame of 2000, proper motion to date, corrected for parallax). No correction for relativistic light bending. • Declination (\pmdd.ddddddd) - the Declination of the star, GCRS coordinates. No correction for relativistic light bending. • Uncertainty in Right Ascension (mas) - incorporating position, proper motion and parallax uncertainties • Uncertainty in Declination (mas) - incorporating position, proper motion and parallax uncertainties • Angular diameter of star (mas) - using the Gaia estimated star diameter from DR2. For stars added after the beginning of 2021, an estimate based on the star's magnitudes is given as the quantity is not available in EDR3. • Issues flag. 0 = no issues, 1 = high RUWE, 2 = Duplicate source flag, 3 = 1 + 2. - see Notes for explanations • Right Ascension - apparent, hh.hhhhhhh. The apparent RA of the star at the Date+time of the event, with no correction for relativistic light bending. • Declination - apparent (\pmdd.ddddddd) The apparent declination of the star at the Date+time of the event, with no correction for relativistic light bending. • Mb - The Gaia blue magnitude of the star • Mg - The Gaia G magnitude. For non-Gaia stars, the V magnitude • Mr - The Gaia red magnitude of the star. Where available, the Red Photometer magnitude of Gaia • EPIC ID - the identification of stars if they are observed in the Kepler2 mission
Star Issues	<p>Extra details about the star</p> <ul style="list-style-type: none"> • Reliability. A measure of whether the star position is fully reliable. <ul style="list-style-type: none"> ○ For Gaia stars, the value is the RUWE (Renormalised Unit Weight Error). "The RUWE is expected to be around 1.0 for sources where the single-star model provides a good fit to the astrometric observations. A value significantly greater than 1.0 (say, >1.4) could indicate that the source is non-single or otherwise problematic for the astrometric solution." ○ For star positions sourced from TychoGaia: the 'astrometric-excess-noise' parameter ○ For star positions sourced from Hipparcos2: a value computed using the Hipparcos values of Ntr, F2, and the number of parameters in the solution. The result is largely equivalent to RUWE. • Duplicated Source flag. A flag in Gaia. 0 = not set, 1 = set, -1 = not specified (that is, position comes from TychoGaia or Hipparcos2) During data processing, this source happened to be duplicated and only one source identifier has been kept. Observations assigned to the discarded source identifier(s) were not used. This may indicate observational, cross-matching or processing problems, or stellar multiplicity, and probable astrometric or photometric problems in all cases. In Gaia DR1 and DR2, for close doubles with separations below some 2 arcsec, truncated windows have not been processed, neither in astrometry nor photometry. The transmitted window is centred on the brighter part of the acquired window, so the brighter component has a better chance to be selected, even when processing the fainter transit. If more than two images are contained in a window, the result of the image parameter determination is unpredictable in the sense that it might refer to either (or neither) image, and no consistency is assured.

	<ul style="list-style-type: none"> • No proper motion flag. Indicates that no proper motion has been specified in the Gaia catalogue. Values are 0 = has proper motion, 1 = no proper motion, -1 = not specified (that is, position comes from TychoGaia or Hipparcos2, which will have proper motions). An RUWE of 0 appears to be applied when there is no proper motion in Gaia. • Proper motion derived using UCAC4. For some stars where there is no proper motion in Gaia, and approximate proper motion was added by comparing the UCAC4 J2000 position with the Gaia 2016 position. Values are 0 = (includes stars with Gaia proper motions, or stars with no Gaia proper motions that were not matched to UCAC4), 1 = proper motion added, -1 = not specified (that is, the position comes from TychoGaia or Hipparcos2) • Double star - ratio of star brightness. Default is 1.2. The ratio is used to determine to location of the Gaia position along the component separation. If R is the ratio (reference/other), the distance of the reference star from the Gaia position is Separation/(R + 1) • Uncertainty in the star brightness ratio, as %. Default is 10 • Double star solution, offset in RA. The offset in RA from the Gaia position, of the component used for the occultation solution. • Double star solution, offset in Dec. The offset in Dec from the Gaia position, of the component used for the occultation solution. • Double star solution, Standard deviation in offset in RA. • Double star solution, Standard deviation in offset in Dec.
<p>Asteroid</p>	<p>Details of the asteroid</p> <ul style="list-style-type: none"> • Number - the number of the asteroid • Name - the asteroid's name, or other identification [the name of asteroid (229762) G!kun 'homdima is held as Gunhoumdima] <p>Positions on the Apparent fundamental plane are computed using orbital elements at the Date + time of the event, with the shadow motion being expressed as $a*T + b*T^2 + c*T^3$, where T is the time (in hours) from the hour under Date. The following give the coefficients for this expression.</p> <ul style="list-style-type: none"> • dX - coefficient 'a' in X (Earth radii/hr) • dY - coefficient 'a' in Y (Earth radii/hr) • d2X - coefficient 'b' in X (Earth radii/hr²) • d2Y - coefficient 'b' in Y (Earth radii/hr²) • d3X - coefficient 'c' in X (Earth radii/hr³) • d3Y - coefficient 'c' in Y (Earth radii/hr³) • Parallax - in arcsec, at the hour under Date • dParallax - in arcsec. The hourly rate of change in parallax • Nominal mean diameter - in km. Typically from IR satellite measurements • Uncertainty in that diameter - km (added in v2.2) • Mv - the Visual magnitude of the asteroid
<p>Solve Flags</p>	<p>Flags for automatic fitting</p> <p>A number of parameters can be set for automatic fitting - and this is indicated by a flag. The flag is:</p> <ul style="list-style-type: none"> • 0 if the parameter has not been included in the automatic fitting • 1 if the parameter was included in the automatic fitting of an ellipse to observed chords

	<p>The parameters for which the flags are set are:</p> <ul style="list-style-type: none"> • X coordinate • Y coordinate • Major Axis • Minor Axis • PA Major Axis • Circular solution • Include Miss events • Separation of 2nd star/asteroid moon • PA of 2nd star/asteroid moon
<p>Elliptic Fit</p>	<p>Details of the fit of an ellipse to the observed chords</p> <ul style="list-style-type: none"> • X - X-coordinate of the center of the best-fit ellipse (in km) relative to the reference frame used to plot the observations • Y - Y-coordinate of the center of the best-fit ellipse (in km) relative to the reference frame used to plot the observations • Major axis - in km • Minor Axis - in km • PA Major Axis - in deg • Fit quality - a code indicating the quality of the fit <p>0 = 'No reliable position or size' 1 = 'Astrometry only. No reliable size' Observation can be used to report astrometry, but nothing meaningful about the asteroid's size. 2 = 'Limits on size, but no shape'. Poor coverage around the profile, but a diameter is determinable (often with a fit to a shape model) 3 = 'Reliable size. Can fit to shape models'. Good coverage around much of the profile enabling a reliable determination of the asteroid's size - even without a shape model 4 = 'Resolution better than shape models'. Profile of the asteroid well covered with highly consistent results</p> <ul style="list-style-type: none"> • Used Assumed Diameter - flag to indicate the major/minor axes are assumed values (e.g. from IR satellite measures) rather than derived from the observation. • Flag to indicate the event should be reviewed in the future because of particular issues that might be resolved with further information (0 = false, 1 = true) • X-offset from X to the Center of Mass location - in km • Y-offset from Y to the Center of Mass location - in km
<p>Ellipse Uncertainty</p>	<p>The standard deviations of the values for the fitted ellipse</p> <ul style="list-style-type: none"> • X - X-coordinate of the center of the best-fit ellipse relative to the reference frame used to plot the observations (km) • Y - Y-coordinate of the center of the best-fit ellipse relative to the reference frame used to plot the observations (km) • Major axis - in km • Minor Axis - in km • PA Major Axis - in deg

<p>Shape-Model Fit</p>	<p>Where shape models are available, this group gives data about the fits to shape models</p> <p>Each shape model has its own group with the tags <Fit> </Fit>. The items within each such group are:</p> <ul style="list-style-type: none"> • Source - The shape model source name (DAMIT, ISAM) • ID - the identification within that source • SurfaceDia/VolumeDia ratio - the ratio of the Surface-equivalent diameter to the Volume-equivalent diameter of the shape model. • Fit quality - a flag to indicate whether the model is consistent with the occultation observations. <ul style="list-style-type: none"> 0 = Not fitted. Too few chords to make a fit to the shape model. 1 = Bad occn data. The occultation observations are either inconsistent or unreliable, with no ready way of distinguishing between reliable and unreliable observations 2 = Model wrong. The shape model is clearly inconsistent with the observed chords 3 = Minimum Dia. Usually associated with a single chord observation, with that chord being matched to the largest dimension of the shape model to give its minimum diameter 4 = Diameter but no fit. The chords do not sensibly match the shape model, yet it is possible to derive minimum and maximum possible diameters. [NOTE: flag 1 - Model wrong - should be used unless there is a degree of confidence that the derived diameters are 'in the right ball-park'] 5 = Poor fit. The shape model is generally consistent with the observed chords - but has some broad deviations 6 = Good fit. The shape model has a high degree of correspondence with the observed chords. 7 = Not constrained. The observations have been compared to the shape model, but the distribution of the chords, or the magnitude of the uncertainties, were such that no meaningful constraints could be determined. Setting 7 added with effect from May 2022 • Phase correction - the rotational correction (in degrees) applied to optimize the fit. Only applied if the light curve data warrants such an adjustment. • Volume Dia Min - the minimum volume-equivalent diameter arising from a fit of the chords to the shape model • Volume Dia Max - the maximum volume-equivalent diameter arising from a fit of the chords to the shape model • Version - information about the version
<p>Satellite</p>	<p>Details of an observed companion to an asteroid</p> <p>This group only appears if the observation shows the presence of two bodies.</p> <p>As at 2019, the fit to the satellite is 'manual', so there are no determined standard deviation values</p> <ul style="list-style-type: none"> • IAU designation of companion • Sat_dRA - motion of the satellite in Right Ascension relative to the system's center of mass. Units are mas/hr. The zero time is same as for the motions of the main body. [Note this and the following three items are only set if a Miriade ephemeris is available for the system. Otherwise the values are set to zero. These values are only used to align the chords of the satellite.] • Sat_dDec - motion in Declination relative to the system's center of mass • Sat_d2RA - 2nd order motion in Right Ascension relative to the system's center of mass • Sat_d2Dec - 2nd order motion in Declination relative to the system's center of mass • Separation (mas) • PA (deg) PA of companion with respect to the main body - Apparent reference frame • Uncertainty in Separation (mas) • Uncertainty in PA • Major axis (km) - of the companion • Minor Axis (km) - of the companion • PA Major Axis (Deg) - of the companion

	<ul style="list-style-type: none"> • Fit quality <ul style="list-style-type: none"> ○ None No fit to the satellite. This is only used when the observations indicate the detection of a satellite, but the observations have not been analyzed to obtain a fit to the observations. ○ Is it a satellite? The observations indicates the possibility of a satellite. However the observational evidence is not sufficient to assert a definite detection. [Single-chord visual observations would typically fall into this category, as well as single noisy video recordings] ○ Approx offset The existence of a satellite is reasonably definite. The approximate location of the satellite can be determined, but not its size or shape ○ Offset + size An accurate location location of the satellite is determined, together with a size derived by assuming it is spherical ○ Offset + shape An accurate determination of the location, size and shape of the satellite.
--	---

DoubleStar	<p>Details of double star solutions</p> <p>This group only appears if the observation indicates the star is double.</p> <p>The number of times this line can appear depends on the circumstances of the event, as follows:</p> <p>1 - if there are two or more spaced chords for both the primary and secondary star, such that there is no doubt about which side of the asteroid the primary or secondary star passed as seen by the observers. This provides a unique solution.</p> <p>2 - if there are two or more spaced chords for one component of the pair - such that there is no doubt about which side of the asteroid that component passed. However if the other component does not have sufficient chords to determine which side of the asteroid it passed, there are two possible solutions.</p> <p>4 - if the number of observed chords is insufficient to locate either component against one or other side of the asteroid, leading to 4 possible solutions. This situation most commonly occurs with single-chord events, but it also occurs when there are two or more chords which happen to be closely spaced such that the relevant side of the asteroid cannot be determined.</p>			
	<table border="1" style="width: 100%;"> <thead> <tr> <th style="width: 15%; text-align: center;">Tag</th> <th style="text-align: left;">Data items</th> </tr> </thead> <tbody> <tr> <td style="text-align: center; vertical-align: middle;">Solution</td> <td> <p>The double star solution, or one of multiple double star solutions.</p> <p>This group is repeated as often as required - 1, 2 or 4 times.</p> <ul style="list-style-type: none"> • PA - the PA of the companion (deg) • Separation - the separation of the components (mas) • Uncertainty in PA • Uncertainty in Separation • Centre in X - for when there are plural solutions • Centre in Y - for when there are plural solutions • Offset in X • Offset in Y • Solution number <p>The Offsets in X and Y apply when there are insufficient chords to locate the primary star on one side or the other of the asteroid. In this situation there are 4 potential solutions:</p> <ul style="list-style-type: none"> * primary star on one side of the asteroid, with secondary on one or the other side; and * primary star on other side of asteroid, with secondary on one or the other side. <p>The offset value places the primary star one one or other side of the asteroid, avoiding the need to re-solve for the position of the asteroid. The astrometric position is for the mean relative location of the primary star.</p> </td> </tr> </tbody> </table>	Tag	Data items	Solution
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Solution	<p>The double star solution, or one of multiple double star solutions.</p> <p>This group is repeated as often as required - 1, 2 or 4 times.</p> <ul style="list-style-type: none"> • PA - the PA of the companion (deg) • Separation - the separation of the components (mas) • Uncertainty in PA • Uncertainty in Separation • Centre in X - for when there are plural solutions • Centre in Y - for when there are plural solutions • Offset in X • Offset in Y • Solution number <p>The Offsets in X and Y apply when there are insufficient chords to locate the primary star on one side or the other of the asteroid. In this situation there are 4 potential solutions:</p> <ul style="list-style-type: none"> * primary star on one side of the asteroid, with secondary on one or the other side; and * primary star on other side of asteroid, with secondary on one or the other side. <p>The offset value places the primary star one one or other side of the asteroid, avoiding the need to re-solve for the position of the asteroid. The astrometric position is for the mean relative location of the primary star.</p>			

Astrometry	<p>Details of the astrometric solution derived from the event</p> <p>This group only appears if the quality setting under EllipticFit is greater than 0.</p> <p>There are three groups under this heading:</p>	
	Tag	Data Items
	ReferenceTime	<p>The time used for reporting an event.</p> <p>If the event involves a satellite, this time is the average of all events involving the satellite that have been used in the solution. This time is used for both the satellite, and the primary body.</p> <p>If the star is a double star, only the primary events are used. The first step in the solution is to identify the location of the center of the asteroid relative to the geocenter, at a time identified by a particular observed event that is used to define the plot axes.</p> <ul style="list-style-type: none"> • Year (yyyy) • Month (mm) • Day (dd) • Reference hour (hh.hhhhhh) • Uncertainty in the reference time (s.sss)
MainBody	<p>Event details at the Reference Time</p> <ul style="list-style-type: none"> • IAU designation • FundamentalPlaneX (km) kkkk.k (apparent) • FundamentalPlaneY (km) kkkk.k (apparent) • dRACosDec (arcsec) - J2000 • dDec (arcsec) - J2000 • UncertRA (arcsec) - uncertainty in Time included. This data element is not used. Final RA uncertainty is based on along/across track uncertainties and time uncertainty. • UncertDec (arcsec) - uncertainty in Time included. This data element is not used. Final Dec uncertainty is based on along/across track uncertainties and time uncertainty. • Position centered on shape model (0=false, 1=true). Set to false if <EllipticFit>, X-offset or Y-Offset, are non-zero • number of chords used • Position is for an unseen primary of a binary asteroid (0=false, 1=true), and is used solely as the origin for the position of the satellite. <p style="text-align: center;">The values of dRACosDec and dDec are 'observed' values. They have been converted from the Apparent reference frame to J2000. They have not had the effects of deflection of the asteroid relative to the star removed.</p> <ul style="list-style-type: none"> • Fit code - uncertainty in position of center of asteroid. <p style="text-align: center;">Parts of the Fit code use the following 4 parameters relating to the locations of the maximum and minimum hit chords, and the location of the closest Miss chords (expressed in units of the asteroid's assumed radius)</p>	

Well-located : PlusHit ≥ 0.3 and MinusHit ≤ -0.3

Poorly-Located : (PlusHit - MinusHit) > 0.5 , with either PlusHit < 0.3 or MinusHit > -0.3

Constrained : either PlusMiss < 1.3 or MinusMiss > -1.3

Unconstrained - none of the above

The fit uncertainty categories are:

Default setting

(a) - the uncertainty from a least squares fit to an ellipse, unqualified. [This is usually replaced by one of the following. However it will appear for occultations by the major planets and larger planetary satellites, when they have a known diameter and are known to be spherical.]

(b), (c) and (d) - REPLACE the default setting with uncertainties as follows:

(b) - when the solution is fitted to the Center of Mass (or of a shape model) - set at 2% of diameter for both x & y

(c) - if not b, but has a shape model fit of either 'poor' or 'good'

c1 If quality = 'Reliable Size' or better - set at 4% of diameter for both x & y

c2 If quality = 'Limits on size, but no shape'- set at 8% of diameter for both x & y

(d) - for major planets & their large moons. [This relies on them being essentially circular in profile, and their diameters being accurately known - to provide good astrometry in circumstances which would not apply to asteroids.]

d1 - if Well-located, the unchanged uncertainty of the fit

d2 - if Poorly-located, 3 times the uncertainty of the fit 4% of assumed diameter

d3 - if Constrained:

(i) if only 1 chord, or the spread of the chords is less than 5% of the diameter,

- If the motion in the time uncertainty period is greater than the along-track uncertainty, that motion distance is taken as the along-track uncertainty. The along-Track and across-Track uncertainties are taken as this value.
- otherwise the along-track and across-track are the uncertainties from the fit

(ii) if not (i), the along-track and across-track are the uncertainties from the fit.

(iii) **in both cases**, the along-track uncertainty is increased according to the distance from the center of the object. The across-track uncertainty is increased as the distance from the center of the object is reduced from the edge.

		<p>d4 - if Not-constrained:</p> <p>(i) If only one chord,</p> <ul style="list-style-type: none"> ▪ the along-track uncertainty is computed on the same basis as for 'd3 - if Constrained', (i), first dot point. ▪ If the chord is located more than 2 arc-sec from the center of the object, the across-track uncertainty is computed on the same basis as for 'd3 - if Constrained', (i), first dot point. ▪ otherwise the across-path uncertainty is set as 50% of the object's radius <p>(ii) If more than one chord</p> <ul style="list-style-type: none"> ▪ the along-track uncertainty is computed on the same basis as for 'd3 - if Constrained', (i), first dot point. ▪ if the average distance of the chords from the center of the object is greater than 25% of its radius, and the distance covered by the chords is greater than 5% of the radius, OR the average distance is greater than 15%, and the distance covered is greater than 10%, the across-track uncertainty is the uncertainty from the fit ▪ otherwise the across-path uncertainty is set as 50% of the object's radius <p>(iii) <i>in both cases</i>,</p> <ul style="list-style-type: none"> ▪ the along-track uncertainty is increased according to the distance from the center of the object. ▪ the across-track uncertainty is increased as the distance from the center of the object is reduced from the edge - except for (ii) third dot point. <p>(e) - MODIFIES the values from (a) by specifying a minimum value (separately considered in x & y)</p> <p>e - for events where quality is better than 'Astrometry only'; and either Major + Minor axes are included in Least Squares solution, or the solution is for a circle:</p> <p>Limits on size, but no shape</p> <p>e1 - Well-located - uncertainty must be at least 8% of diameter</p> <p>e2 - Poorly-located - uncertainty must be at least 12% of diameter</p> <p>e3 - Constrained - uncertainty must be at least 16% of diameter</p> <p>e4 - Unconstrained - uncertainty must be at least 20% of diameter</p> <p>'Reliable size', or 'Better than Shape models'</p> <p>e5 - Well-located - uncertainty must be at least 5% of diameter</p> <p>e6 - Poorly-located - uncertainty must be at least</p>
--	--	---

		<p>8% of diameter e7 - Constrained - uncertainty must be at least 12% of diameter e8 - Unconstrained - uncertainty must be at least 16% of diameter (f) - REPLACES the Default setting as follows f - if none of (b) to (e) apply:</p> <p>Along-track uncertainty set on following basis: For each chord: if chord length > 0.8 of assumed diameter - along track uncertainty set at 5% of diameter if chord length > 0.6 of assumed diameter - along track uncertainty set at 10% of diameter Otherwise - along track uncertainty set at 20% of diameter Final value - mean of the along track uncertainties, assessed in inverse quadrature (to give greater significance to smaller uncertainty values).</p> <p>Across-track uncertainty set on following basis: f1 - if Well-located, asteroid diameter uncertainty f2 - if Poorly-located, 2 x asteroid diameter uncertainty f3 - if Constrained, 2 x asteroid diameter uncertainty f4 - if Unconstrained, 40% of assumed</p> <ul style="list-style-type: none"> ○ Adjustment to the across-track uncertainty for the uncertainty in location of the center of mass of the asteroid (km) ○ Adjustment to the along-track uncertainty for the uncertainty in location of the center of mass of the asteroid (km) ○ Maximum +ve Hit distance, asteroid radii d.dd (always set) ○ Maximum -ve Hit distance, asteroid radii -d.dd (always set) ○ Minimum +ve Miss distance, asteroid radii d.dd; 9 = not set ○ Maximum -ve Miss distance, asteroid radii -d.d; -9 = not set
	<p>Main At Conjunction</p>	<p>Event details at for the time of Geocentric Conjunction</p> <ul style="list-style-type: none"> ● IAU designation ● GeocentricX at Conjunction (km) kkkk.k ● GeocentricY at Conjunction (km) kkkk.k ● Year of Conjunction ● Month of Conjunction ● Day of Conjunction dd.ddddddd ● Standard Deviation in Time of Conjunction d.ddddddd ● Standard deviation Along-track (mas) (s.s) - from fit only, SDev in Time of Conj not included ● Separation at conjunction (arcsec) ss.ssss ● Standard deviation Across-track {Separation} (mas) (s.s)

		<ul style="list-style-type: none"> • Position Angle of Conjunction (deg) ddd.ddd • Position is for an unseen primary of a binary asteroid (0=false, 1=true), and is used solely as the origin for the position of the satellite <p>The values are 'observed' values. They have been converted from the Apparent reference frame to J2000. They have not had the effects of deflection of the asteroid relative to the star removed.</p>
	<p style="text-align: center;">Secondary</p>	<p>Event details at the Reference Time</p> <ul style="list-style-type: none"> • IAU designation • GeocentricX (km) kkkk.k • GeocentricY (km) kkkk.k • PA (deg) PA of companion with respect to the main body - J2000 reference frame • dRACosDec (arcsec) • dDec (arcsec) • UncertRA (arcsec) • UncertDec (arcsec) • number of chords used <p>The values of dRACosDec and dDec are 'observed' values, They have been converted from the Apparent reference frame to J2000. They have not had the effects of deflection of the satellite relative to the star removed.</p>
	<p style="text-align: center;">Secondary At Conjunction</p>	<p>Event details at for the time of Geocentric Conjunction</p> <ul style="list-style-type: none"> • IAU designation • Satellite motions (from Miriade) allowed for in the solution. 0 = no, 1 = yes • GeocentricX at Conjunction (km) kkkk.k • GeocentricY at Conjunction (km) kkkk.k • Year of Conjunction • Month of Conjunction • Day of Conjunction dd.dddddd • Standard Deviation in Time of Conjunction d.dddddd • Standard deviation Along-track (mas) (s.s) • Separation at conjunction (arcsec) ss.ssss • Standard deviation Across-track {Separation} (mas) (s.s) • Position Angle of Conjunction (deg) ddd.ddd <p>The values are 'observed' values. They have been converted from the Apparent reference frame to J2000. They have not had the effects of deflection of the asteroid relative to the star removed.</p>
	<p style="text-align: center;">MPC</p>	<p>Details of publication by the Minor Planet Center</p> <ul style="list-style-type: none"> • Date of publication • Circular number

Observations	This provides a series of groups giving details for each observer					
	There are two groups under this heading.					
	Tag	Data items				
Prediction	<p>Details for a predicted central line location near the observed locations</p> <p>The prediction information is used to validate the observed data, and to calculate the offset between prediction and observed</p> <ul style="list-style-type: none"> • Sequential reference number • Prediction Longitude (\pmddd mm ss.s) • Prediction Latitude (\pmdd mm ss.s) • Time (hh mm ss.s) The time is always positive. For events near 0hrs UT, the hour can be 24 or more • Event comments. A free-text field for overall comments about the event - such as why no astrometry is reported. Field added at start of 2021 - and is incomplete for earlier years. From Nov 2021, field includes the source of the orbit used for the prediction in this tag. 					
Observer	<p>Observer details.</p> <p>This group is repeated as often as required</p> <p>There are four groups under this heading.</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="background-color: #d9e1f2; text-align: center;">Tag</th> <th style="background-color: #d9e1f2;">Data Item</th> </tr> </thead> <tbody> <tr> <td style="background-color: #d9e1f2; text-align: center; vertical-align: middle;">ID</td> <td> <p>Details of the observer and equipment</p> <ul style="list-style-type: none"> • Sequential reference number • Name 1 • Name 2 • More Than 2 observers • located near • State or country (2 or 3 letter code) • Longitude (\pmddd mm ss.s) • Latitude (\pmdd mm ss.ss) • Alt (m) • Datum <ul style="list-style-type: none"> _ = WGS84 N = NAD1927 E = ED1950 T = Tokyo G = GB1936 * = unspecified, or other. • Telescope Aperture (cm) • Telescope Type <ul style="list-style-type: none"> _ = unstated 1 = Refractor 2 = Newtonian 3 = SCT 4 = Dobsonian 5 = Binoculars 6 = Other </td> </tr> </tbody> </table>		Tag	Data Item	ID	<p>Details of the observer and equipment</p> <ul style="list-style-type: none"> • Sequential reference number • Name 1 • Name 2 • More Than 2 observers • located near • State or country (2 or 3 letter code) • Longitude (\pmddd mm ss.s) • Latitude (\pmdd mm ss.ss) • Alt (m) • Datum <ul style="list-style-type: none"> _ = WGS84 N = NAD1927 E = ED1950 T = Tokyo G = GB1936 * = unspecified, or other. • Telescope Aperture (cm) • Telescope Type <ul style="list-style-type: none"> _ = unstated 1 = Refractor 2 = Newtonian 3 = SCT 4 = Dobsonian 5 = Binoculars 6 = Other
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ID	<p>Details of the observer and equipment</p> <ul style="list-style-type: none"> • Sequential reference number • Name 1 • Name 2 • More Than 2 observers • located near • State or country (2 or 3 letter code) • Longitude (\pmddd mm ss.s) • Latitude (\pmdd mm ss.ss) • Alt (m) • Datum <ul style="list-style-type: none"> _ = WGS84 N = NAD1927 E = ED1950 T = Tokyo G = GB1936 * = unspecified, or other. • Telescope Aperture (cm) • Telescope Type <ul style="list-style-type: none"> _ = unstated 1 = Refractor 2 = Newtonian 3 = SCT 4 = Dobsonian 5 = Binoculars 6 = Other 					

			<p>7 = None 8 = eVscope</p> <ul style="list-style-type: none"> • Observing method <ul style="list-style-type: none"> unspecified a Analogue & digital video b Digital SLR-camera video c Photometer d Sequential images e Drift scan f Visual g Other • Time Source <ul style="list-style-type: none"> unspecified a GPS b NTP c Telephone (fixed or mobile) d Radio time signal e Internal clock of recorder [such as by calibrating the recorder well before and after the event] f Stopwatch g Other
		<p>Conditions</p>	<p>Observing Conditions</p> <ul style="list-style-type: none"> • Stability <ul style="list-style-type: none"> _ = unstated 1 = Steady 2 = Slight flickering 3 = Strong flickering • Transparency <ul style="list-style-type: none"> _ = unstated 1 = Clear 2 = Fog 3 = Thin cloud <2 [mag loss <2 mag.] 4 = Thick cloud >2 [mag loss >2 mag.] 5 = Broken opaque cloud [that is, observed thru gaps in the cloud] 6 = Star faint 7 = By averted vision • SN • Time Adjustment (\pms.ss) [Adjustment to time base of observer, to fit to other observations] • Free-text comments
		<p>D</p>	<p>Details of the D event</p> <ul style="list-style-type: none"> • hh mm ss.ss. Always +ve values. For events near 0hrs UT, the hour can be 24h or more • event Code <ul style="list-style-type: none"> D for main star d for 2nd star G for satellite with main star g for satellite with 2nd star

			<p>M applies to situations where an occultation event could not be reliably detected. Most commonly this relates to a situation where the object did not occult the star. However there may be other explanations for the non-detection.</p> <p>m applies to situations where an occultation event involving a 2nd star of a double star could not be reliably detected. Most commonly this relates to a situation where the object did not occult the 2nd star. However there may be other explanations for the non-detection.</p> <p>N for events involving a ring. The D and R times are for opposite arms of a ring. Where there is a D+R for an arm of a ring, the mid-time is specified, with the duration being given in FREE_TEXT</p> <p>n for asteroids (or planets) known to have one or more rings, and an occultation by that ring(s) could not be reliably detected. Most commonly this relates to the star not crossing the orbit of any ring, or the absence of material in the portion of a ring crossed by the star. However there may be other explanations for the non-detection.</p> <p>C for Not Seen - e.g. because of cloud</p> <p>e for an artificial D time of the primary body of an asteroid with satellites - for use when the primary component is not observed. Always a predicted location and time.</p> <ul style="list-style-type: none"> • Accuracy (s.ss) [usually specified by the observer. See below for default values when not specified.] • PEqn (s.s) • Weight [Usually set as 'blank'. See below for default values that are then applied] • Include in Solution Code <ul style="list-style-type: none"> _ Include observation x Exclude observation y Include D only z Include R only
		<p>R</p>	<p>Details of the R event</p> <ul style="list-style-type: none"> • hh mm ss.ss. Always +ve values. For events near 0hrs UT, the hour can be 24h or more • event Code <p>R for main star r for 2nd star B for satellite with main star b for satellite with 2nd star</p> <p>M applies to situations where an occultation event could not be reliably detected. Most commonly this relates to a situation where the object did not occult the star. However there may be other explanations for the non-detection.</p> <p>m applies to situations where an occultation event</p>

involving a 2nd star of a double star could not be reliably detected. Most commonly this relates to a situation where the object did not occult the 2nd star. However there may be other explanations for the non-detection.

N for events involving a ring. The D and R times are for opposite arms of a ring. Where there is a D+R for an arm of a ring, the mid-time is specified, with the duration being given in FREE_TEXT

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C for Not Seen - e.g. because of cloud.

f for an artificial R time of the primary body of an asteroid with satellites - for use when the primary component is not observed. Usually a predicted location and time.

- **Accuracy (s.ss)** [usually specified by the observer. See below for default values when not specified.]
- **PEqn (s.s)**
- **Weight** [Usually set as blank. See below for default values that are then applied.]
- **Include in Solution Code.**
 - _ Include observation
 - x Exclude observation
 - y Include D only
 - z Include R only

Some items have default values:

Accuracy is usually set by the observer. However when not set (which most commonly occurs for observations before 2000) the accuracy is set as follows:

- If the observing Method was 'a', 'b', or 'c'
 - 0.5 sec if the Time Source was 'a', 'd', 'e', 'f';
 - 1.5 sec if the time source was 'b', 'c', or 'g'
- 1.0 sec if the observing Method was 'd', 'e', 'f', or 'g'

Weight is usually set as Blank. When solving for the best fit, the applied weights are:

- 5 - for analogue or digital (non-SLR) video
- 4 - for digital SLR-camera video, and Photometer
- 3 - for sequential images and drift scan
- 1 - for visual and anything else.
- 0 - event is ignored in any solution, but may still be plotted

Miss events are considered only if expressly included in the solution - in which case they are weighted 5.

	<p>Plot code - determines whether an event is plotted in Occult, and by corollary whether the event is reliable in any way. The settings are: <blank> - both events plotted x - neither event is plotted y - only the D event plotted z - only the R event plotted</p>
Added	The date the record was added to the file
Last Edited	The date the record was last edited

5.2 IOTA-ES ASTEROIDAL OCCULTATION - REPORT FORM 2.03

Source: <https://forum.iota-es.de/showthread.php?tid=1>

#IOTA-ES ASTEROIDAL OCCULTATION - REPORT FORM 2.03

#Event
 #Occultation: xxxTIVE
 #DATE: %EVENT-DATE%
 #PREDICTTIME: %EventTimeUT%
 #STAR: %STAR%
 #ASTEROID: %ASTEROID%
 #Nr: %ASTEROID-NO%
 #OBSERVER
 #Observer1:
 #Observer2:
 #moreObs:
 #E-mail:
 #Address:
 #OBSERVING_STATION
 #NearestCity:
 #Countrycode:
 #Coordinates LAT +/-DD MM SS.S LON +/-DDD MM SS.S
 #Latitude:
 #Longitude:
 #Altitude:
 #Datum _blank=WGS84 N=NAD1927 E=ED1950 T=Tokyo G=GB1936 *=unspecified, or other
 #Datum:
 #Teleskop _=unstated 1=Refractor 2=Newtonian 3=SCT 4=Dobsonian 5=Binoculars 6=Other 7=None 8=eVscope
 #Telescope:
 #Aperture in cm
 #Aperture:
 #Focallength in cm
 #Focallength:
 #ObservingMethod _=unspecified a=Analogue & digital video b=Digital SLR-camera video c=Photometer d=Sequential images e=Drift scan f=Visual g=Other
 #ObservingMethod:
 #Observation
 #StartObs:
 #D D=Main Star d=second Star G=satellite main star g=satellite 2nd star N=ring M=non detection +time hh:mm:ss.s
 #D:
 #Acc_D:
 #R R=Main Star r=second Star B=satellite main star b=satellite 2nd star N=ring M=non detection +time hh:mm:ss.s
 #R:
 #Acc_R:
 #EndObs:
 #Duration:
 #Exp_Time:
 #Timesource _=unspecified a=GPS b=NTP c=Telephone (fixed or mobile) d=Radio time signal e=Internal clock of recorder f=Stopwatch g=Other
 #Timesource:
 #Camera:
 #Signal/Noise:
 #Weatherconditions
 #Wind:
 #Temperature:
 #Transparency 1=Clear 2=Fog 3=Thin cloud <2 [mag loss <2 mag.] 4=Thick cloud >2 [mag loss >2 mag. 5=Broken opaque cloud [that is, observed thru gaps in the cloud] 6=Star faint 7=By averted vision
 #Transparency: 3
 #Stability _=unstated 1=Steady 2=Slight flickering 3=Strong flickering
 #Stability:
 #Comments:

5.3 PyMovie/PyOTE installation hints

- 1) It is recommended to **always use the latest programme versions** (currently PyMovie 3.7.3, PyOTE 5.2.0).
- 2) **Bug:** *Wrong occultation times with PyOTE versions 4.2.1, released on 8 February 2022, until version 4.4.8.* With version 4.4.9 the bug was fixed. However, the changelog also lists some other bugs after version 4.4.9, see therefore 1).
- 3) **Old installations with Anaconda3:** For a long time (until July 2022), Anaconda3 was required to install PyMovie/PyOTE. Anaconda3 could require up to 10 GB of disk space. From July 2022, there was a transition to versions that no longer required Anaconda3. However, this transition was also associated with a *change in update handling*. The option to download a new version by simply quitting and restarting the programme has been removed.

On the other hand, there are users who work with other applications that need Anaconda3, so they don't tend to uninstall because of PyMovie/PyOTE. But, there is also a (bit tricky) way to keep PyMovie/PyOTE up to date. If starting PyMovie/PyOTE new versions continue to be displayed, see [Figure 5.2](#).

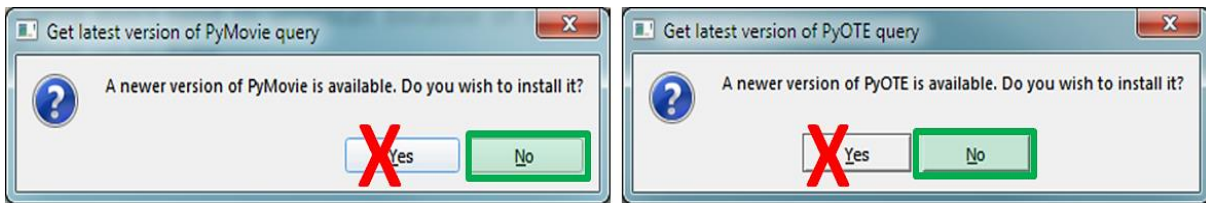


Figure 5.2. PyMovie and PyOTE update offers.

Do not accept the offer to update, otherwise your installation may be destroyed. Press "No" and the programmes open and show the available updates. ([Figure 5.3](#)).

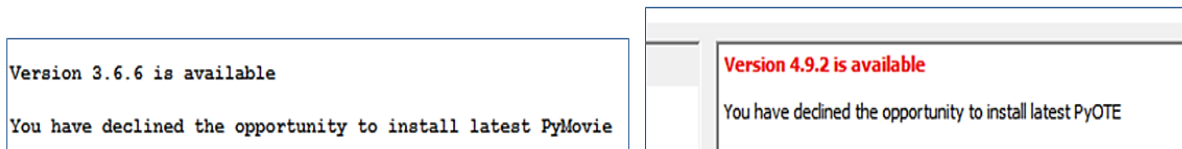


Figure 5.3. Example of update versions displayed by PyMovie and PyOTE.

The names of the available update versions can also be obtained from the PyMovie/PyOTE web repositories. If you know the available versions, the update is done via the command line (C:\Users\[username]>...). For the above examples one would have to type (exactly, in terms of spaces and double ==):

```
C:\Users\[username]>pip install pymovie==3.6.6
C:\Users\[username]>pip install pyote==4.9.2
```

Depending on the Anaconda3 installation and/or if not working as an administrator, it is possible that the Anaconda3 prompt (Anaconda3/Anaconda Prompt) must be used instead of the Windows command line (as shown above).

PyOTE update log example (begin and end):

```
Microsoft Windows [Version 10.0.19044.1865]
(c) Microsoft Corporation. Alle Rechte vorbehalten.
C:\Users\Administrator>pip install pyote==4.9.2
Collecting pyote==4.9.2
  Downloading pyote-4.9.2-py3-none-any.whl (500 kB)
|.....| 500 kB 939 kB/s
Requirement already satisfied: numpy<=1.22 in c:\anaconda3\lib\site-packages (from
pyote==4.9.2) (1.20.3)
...
Requirement already satisfied: attrs>=17.4.0 in c:\anaconda3\lib\site-packages (from
jsonschema->JsonForm>=0.0.2->resource->pyote==4.9.2) (21.2.0)
Installing collected packages: pyote
Attempting uninstall: pyote
Found existing installation: pyote 4.9.1
Uninstalling pyote-4.9.1:
Successfully uninstalled pyote-4.9.1
Successfully installed pyote-4.9.2
C:\Users\Administrator>
```

According to the developer, it is not guaranteed that PyMovie/PyOTE Anaconda3 installations will continue to work/be updatable.

4) Newer versions (from July 2022) no longer require Anaconda3. This option is the best if users do not need Anaconda3. It is recommended for first-time installations and for cases where Anaconda3 has been uninstalled.

There is a detailed installation guide: <https://occultations.org/sw/pymovie/WinPyMoviePyOTE-Install-2022-9-16.zip>. A test installation according to the instructions (W10-64, 22H2, Home) went without problems (Note: The Python version provided in the MS App Store that worked was 3.10.9, the also provided latest version 3.11.1 failed, already the Python installation). **According to the PyMovie/PyOTE developer, both programmes will not run under Python 3.11, a 3.10 Python is required.**

The update process is analogous to 3) via the Windows command prompt:

PyMovie: open a Windows command prompt:

At the > prompt, type: **pip install pymovie==x.x.x** (x.x.x is the new version number)

PyOTE: open a Windows command prompt:

At the > prompt, type: **pip install pyote==x.x.x** (x.x.x is the new version number)

5) PyOTE does not work with pyqtgraph version 0.13.0 and 0.13.1 which is installed with latest PyOTE versions (without Anaconda3). Symptom: “Write report” doesn’t work and the black PyOTE console shows:

```
"AttributeError: module 'pyqtgraph' has no attribute 'GraphicsWindow', Did you mean:
'GraphiCSView'?"
```

Fix: <https://groups.io/g/IOTAoccultations/message/72608> Installation of the older pyqtgraph version 0.12.4 (there is no need to uninstall v 0.13..., the uninstallation occurs automatically during the installation of v 0.12.4): **pip install pyqtgraph==0.12.4**

The issue seems to be generally fixed with latest PyOTE versions.

5.4 Reviewer checklist

It can also be helpful for observers to know how reviewers work.

- 1) Get info: Observation to review (e-mail with country code, HOME page, REVIEW page)
- 2) REVIEW: Open observation
- 3) Is the report/data submitted complete?
- 4) Ask observer if incomplete (E-MAIL & REQUEST CHANGES ON INPUT)
- 5) Data complete?

- 6) Study the event itself (e.g. by the provided Occult4 image, ...)
- 7) Are there other observations of the same event?
- 8) Check all observer entries in the REPORT mask and all additional data and comments for correctness and plausibility
- 9) Correct simple errors (UPDATE ENTRY & SET REVIEWER FIELDS)

- 10) **If non detection:** Check the lightcurve overview image: Indeed no drop? Were SNR and temporal resolution sufficient? Compare lightcurve(s) of reference star(s)
- 11) Ask observer if there is something ... (E-MAIL & REQUEST CHANGES ON INPUT)
- 12) Check again
- 13) Make comments in the log area if required
- 14) ACCEPT or DELETE the report

- 15) **If detection:** Check the lightcurve overview image: Reliable drop? Were SNR and temporal resolution sufficient? Compare lightcurve of reference star(s), are there similar “drops”?
- 16) Ask observer in case of doubt ... (E-MAIL & REQUEST CHANGES ON INPUT)
- 17) Check again, possibly DELETE report, (or maybe, change it to “negative”)
- 18) Check regarding additional drops (secondary events), separate reports required
- 19) If drop seems reliable, check the provided data reduction image and the log- and txt-files regarding data reduction, in case of PyOTE also the False-Positive test image, also have a look at possible steps in D and R (multiple stars?) and possible diffraction effects
- 20) If in doubt, ask observer ... (E-MAIL & REQUEST CHANGES ON INPUT), possibly also ask colleagues from the reviewer team or make a post in the SODIS reviewer forum

- 21) Check again
- 22) If o.k., possibly make additional assessments (D_WT, R_WT, Timeshift, Plotcode)
- 23) Make comments in the log area if required
- 24) ACCEPT the report

- 25) **If uncertain:** See Chapter 1 / [Occult4/SODIS classification of observations](#)

- 26) **If unreliable/inconclusive:** See Chapter 1 / [Occult4/SODIS classification of observations](#)

- 27) Check later again: Are there newly posted observations of the same event?

5.5 FAQ

The following FAQ are not in a logical order and may have already been answered in the text or in the forum.

Are FITS recordings “Sequential images”?

> Yes, and **not** “Analogue & digital video”.

What should be written in the "Comment" field of the report?

> Not much, but essential things not included in the report form (e.g. handling of a rolling shutter or measured delays due to NTP as timing source).

Who can make changes to or delete a *finally* reviewed report?

> An administrator only (on request).

How to quickly find an observation by its #number?

> With the search field on HOME and REVIEW sites.


Is it possible to set several filters (HOME, REVIEW) at the same time?

> Yes.

How to send a REVIEW site (maybe in process) directly to another reviewer?

> Simply via the URL displayed in the browser address bar.

If I found a bug or have a feature request (“FRQ”)?

> Check it carefully and post it to the SODIS  Bug and  Feature Request subforum (<https://forum.iota-es.de/forumdisplay.php?fid=10>).

What about “Date” vs. “Predictdate”?

> “Date” = True Date (UTC) of observer's observation.

“Predictdate” = Date (UTC) that is shown in prediction, e.g. from the Occult4 plot, (**not** , when the prediction was generated).

What about observer names?

> In the report mask, the name of the observer is added automatically (the reason that there is no first observer entry field). If there are several observers, *only* the second observer can be added in the field “Observer 2”. This is optional. If there is no second observer, this field remains empty, please do not add something like *undefined* or so here. If there are three or more observers, the checkbox “More Obs” can be used.

Where in the programme path is the Occult4 database file located?

> It is located under Occult4\Resource Files\Asteroid~Observations.XML. The file is frequently updated by D. Herald.

Where can I find the description of the Occult4 observation XML format?

> From Occult4 help: File formats/Asteroids/Observations XML format and also in [Chapter 5.1](#) of this document

How to stay up to date with the SODIS Forum?

> In the forum, there are options at the bottom: “View Today’s Posts” and “View New posts”. It is advisable to visit the forum regularly, as many relevant questions and topics are discussed there.

How to handle a focal reducer in the report?

> The *effective* focal length must be entered.

How to report a multiple event?

> For multiple events (double stars, secondaries), *several* reports must be submitted.

How to deal with transcontinental events?

> This was discussed recently. S. Preston wrote

(<https://forum.iota-es.de/showthread.php?tid=191&pid=541#pid541>):

"The region with the most reports becomes the "lead" region. All other regions sent their reports to the lead region. The lead region collects and reviews all reports for the events and forwards the full set to Dave Herald.

There is no automated method for detecting events which have reports from multiple regions. However, the regional coordinators usually notice these situations and hand off reports appropriately. The NA reviewer generally check OW to see if they are missing any reports noted on OW. If the regional coordinators don't notice, Dave Herald will notice when he received reports for the same event from multiple regions."

Uploading Tangra lightcurves (xxx.lc)?

> Initially not, but it is possible at the request of the reviewer. The file size can be a problem (e.g. 4 MB did work). PyOTE CSVs are also possible, the file sizes are smaller here.

Negative reports event code?

> "Non detection"(code "M") must be selected. The fields "Duration", "Acc_D" and "Acc_R" must remain empty, to fill in "0" (zero) here is wrong!

Reporting on behalf?

> Observers who do not want to register with SODIS can ask an already registered person to report on their behalf. In this case, the registered user must create a SODIS account under the name of the non-registered observer but with his own e-mail address. The observer's own SODIS account is not affected by this.

How soon should I send my observation to SODIS?

> Within a week is ideal, at least within 14 days.