Flash Detection Software

Theory Section

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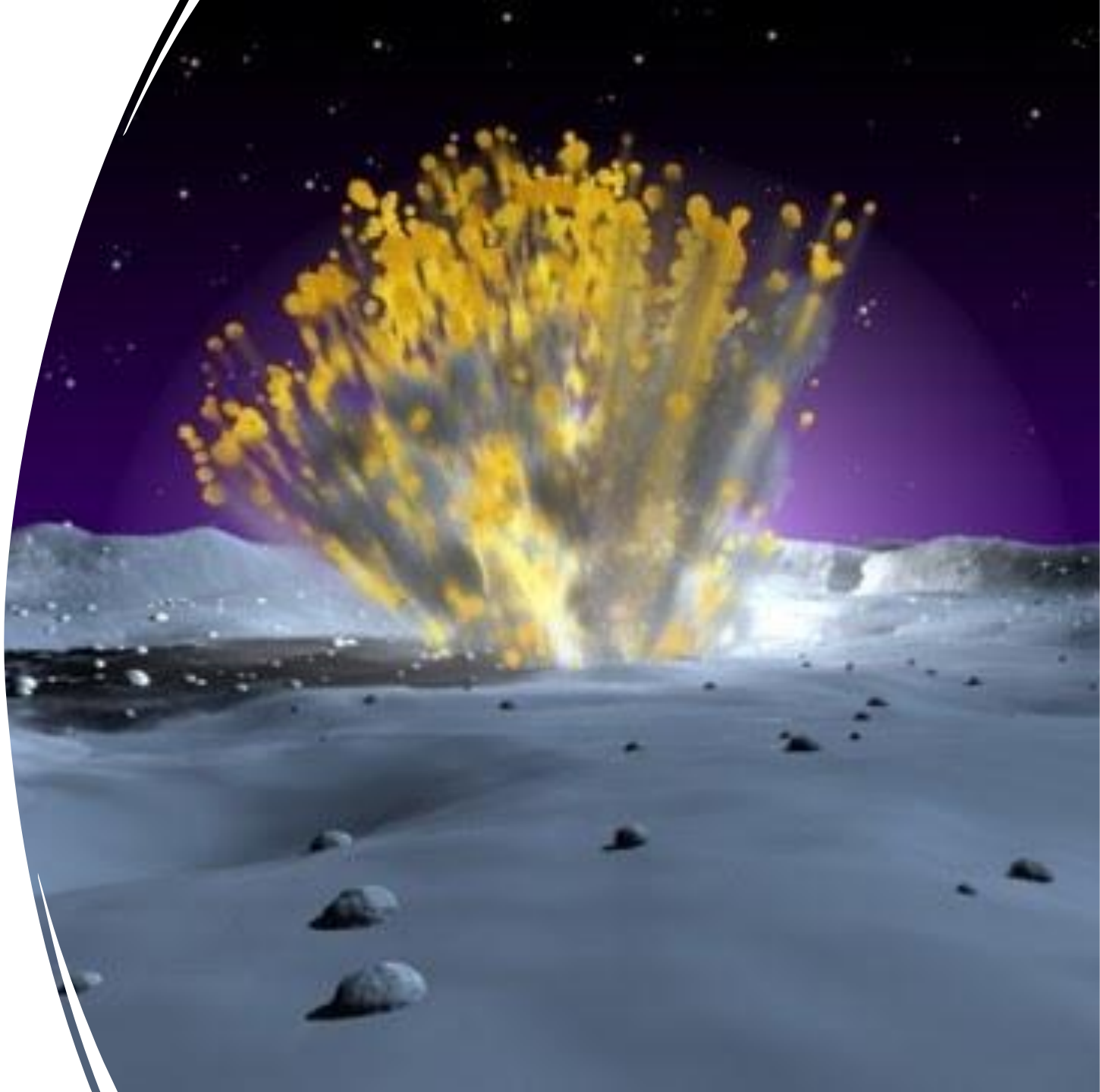
Why we need an open-source tool for lunar impact flash detection?

More impact flashes caught on camera

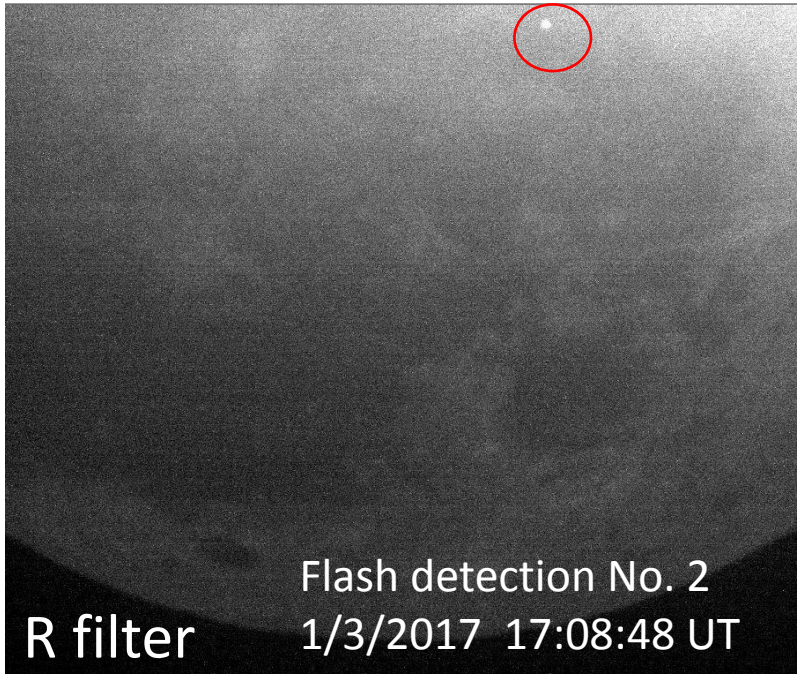
- Moon is bombarded sporadically with a rate of **7.5 met/hr**, while Earth with a rate of ~100 met/h (mesosphere meteors) and with a rate of ~175 met/h at LEO
- Observe Moon for impact flashes at 0.1-0.45 lunar phases ~5-8 nights/month ~ 20´- 4.5 hr

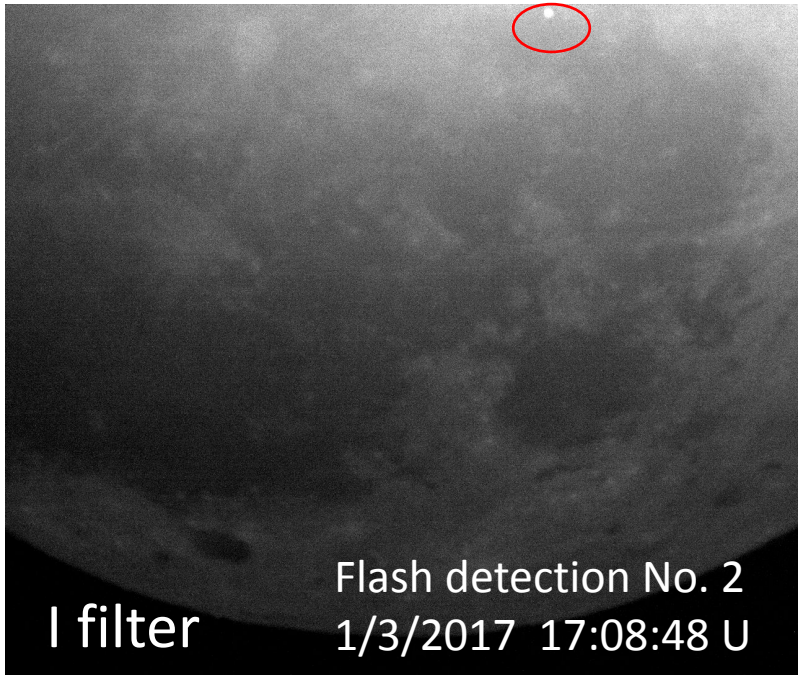
Suggs et al. (2012):	1.03×10^{-7} flash/hr/km^2
Rembold & Ryan (2015):	1.09×10^{-7} flash/hr/km^2
NELIOTA:	2.30×10^{-7} flash/hr/km^2



Cross-validation of impact events across users

- Cosmic ray could be falsely classified as an impact flash
- NELIOTA solves this problem with R, I filters

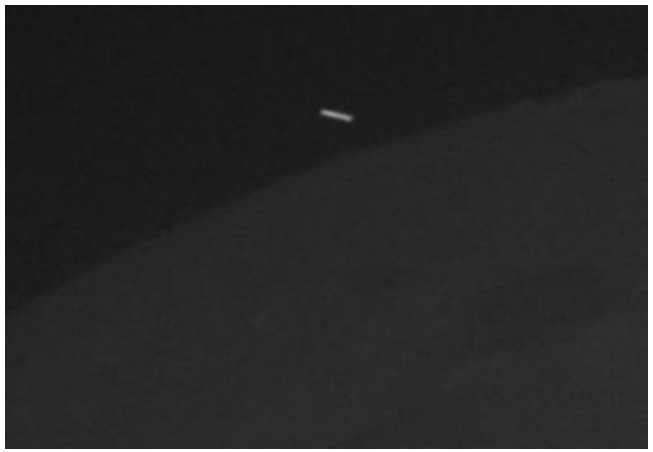


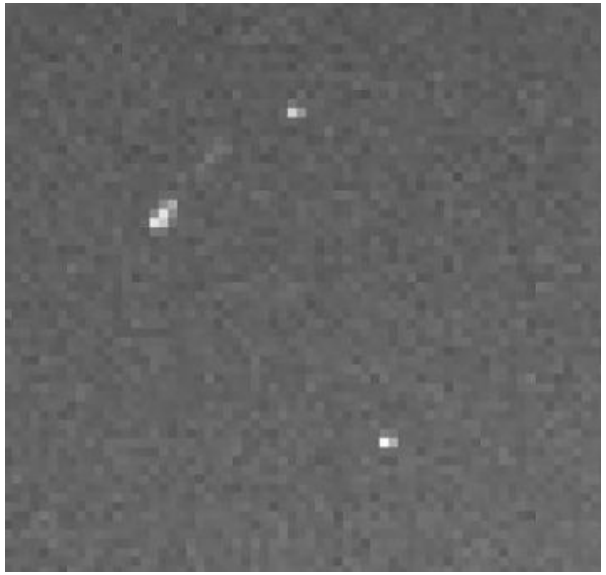


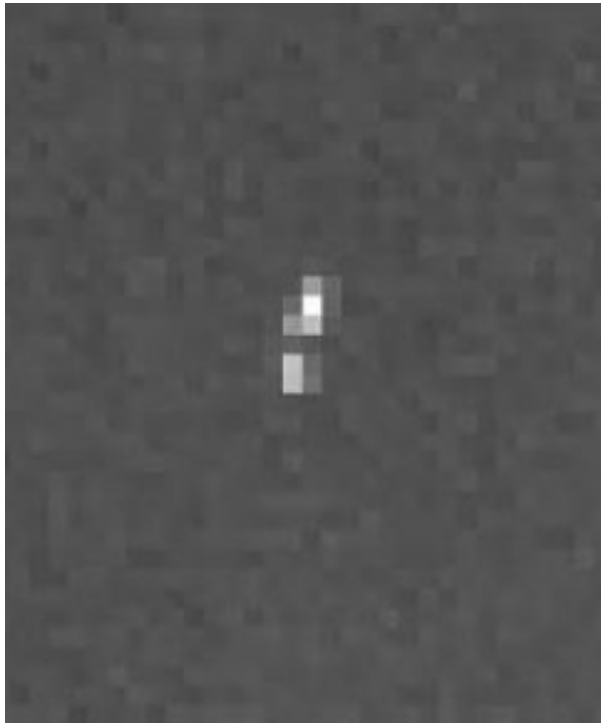
True Impact Flash

- 2 frames in R
- 4 frames in I
- R= 6.7 mag
- I= 6.0 mag

False Impact Flashes







More observation hours!

- Non-sunlit side
- Observation area: 3×10^6 km^2 (in NELIOTA System Setting)

Challenges of an open-source tool for amateurs astronomers

Many different Cameras and Telescopes

- Camera Interface
- Camera write/read time
- Camera video bits
- Camera fps
- Telescope Interface
- Hardware Limitations in the Computer

Storage Limitations

- One night of observation in NELIOTA is about 100GB of data
- We need simultaneous observation and detection of potential events

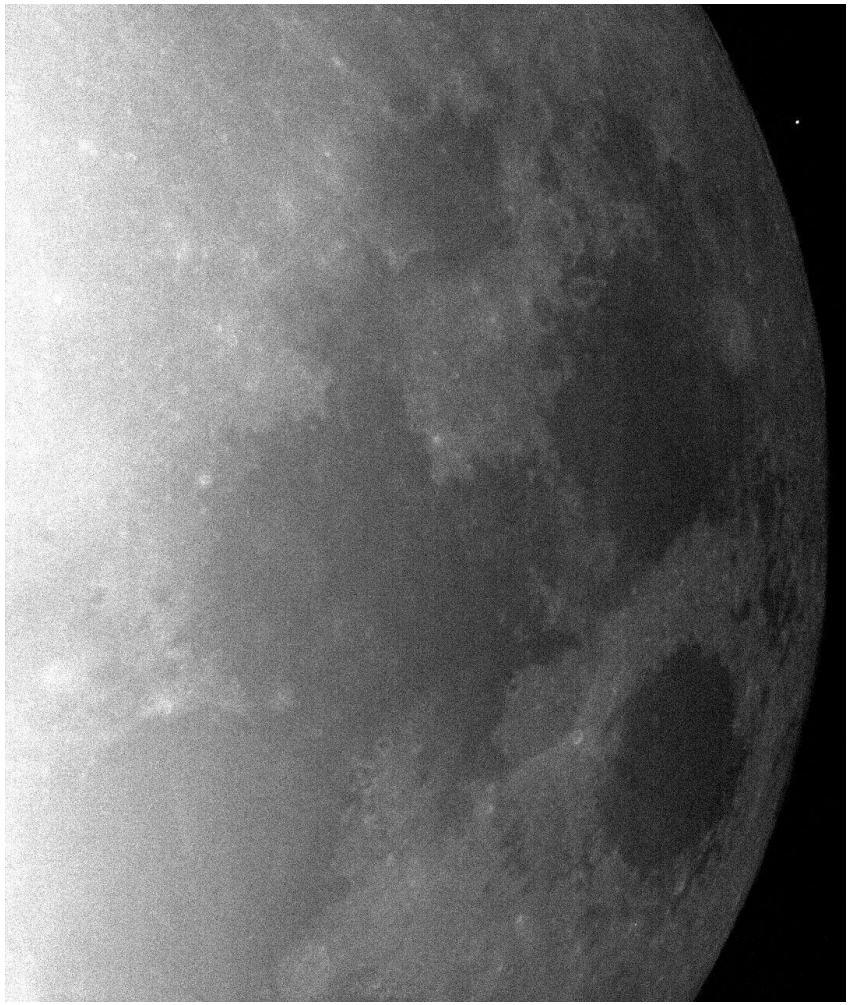
NELIOTA Statistics

- 194.04 hrs Lunar observation
- 152.75TB of data

Optimal observations of the moon

What is an optimal observation?

- Non-sunlit side
- Phases between ~0.1- 0.5
- Standard star observations every ~15 min
- Clear sky, without clouds and pollution
- Observations above ~20 deg



Non-Optimal observations of the moon

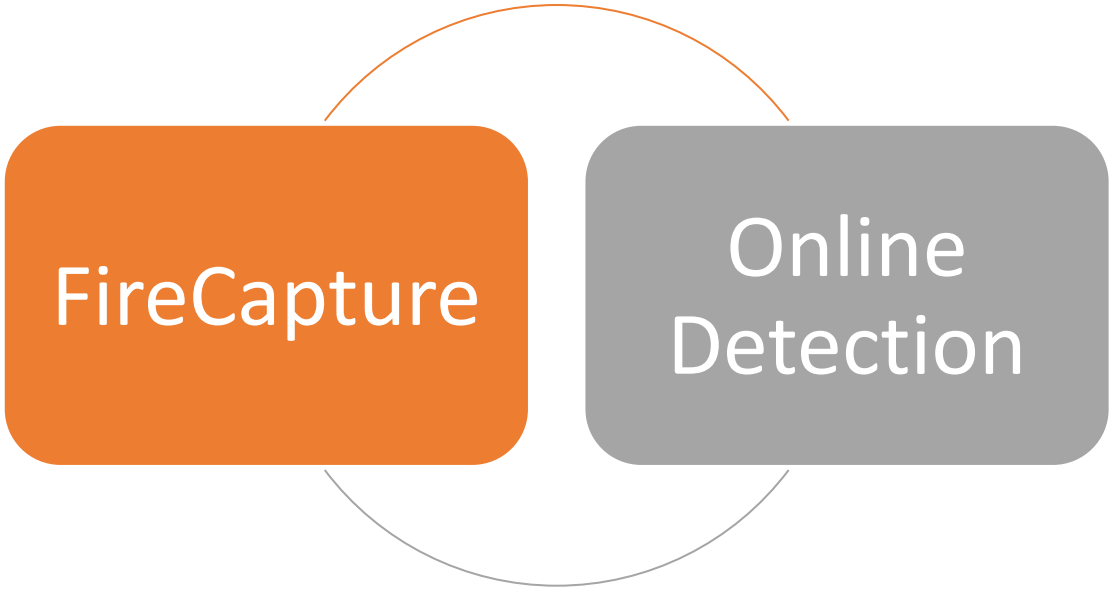
- Ø Include sunlit side (saturation)
- Ø Phases above ~0.5 (straylight)
- Ø Air pollution and clouds
- Ø Observations below ~20 deg

The open-source tool for lunar impact flash detection

Structure of the Tool

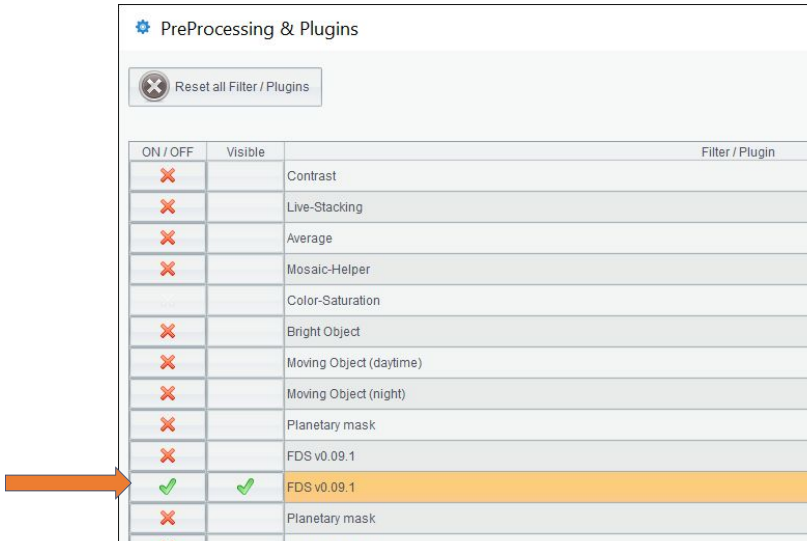
- Observation and Online Detection Domain
- Offline Detection Domain
- Localization Domain

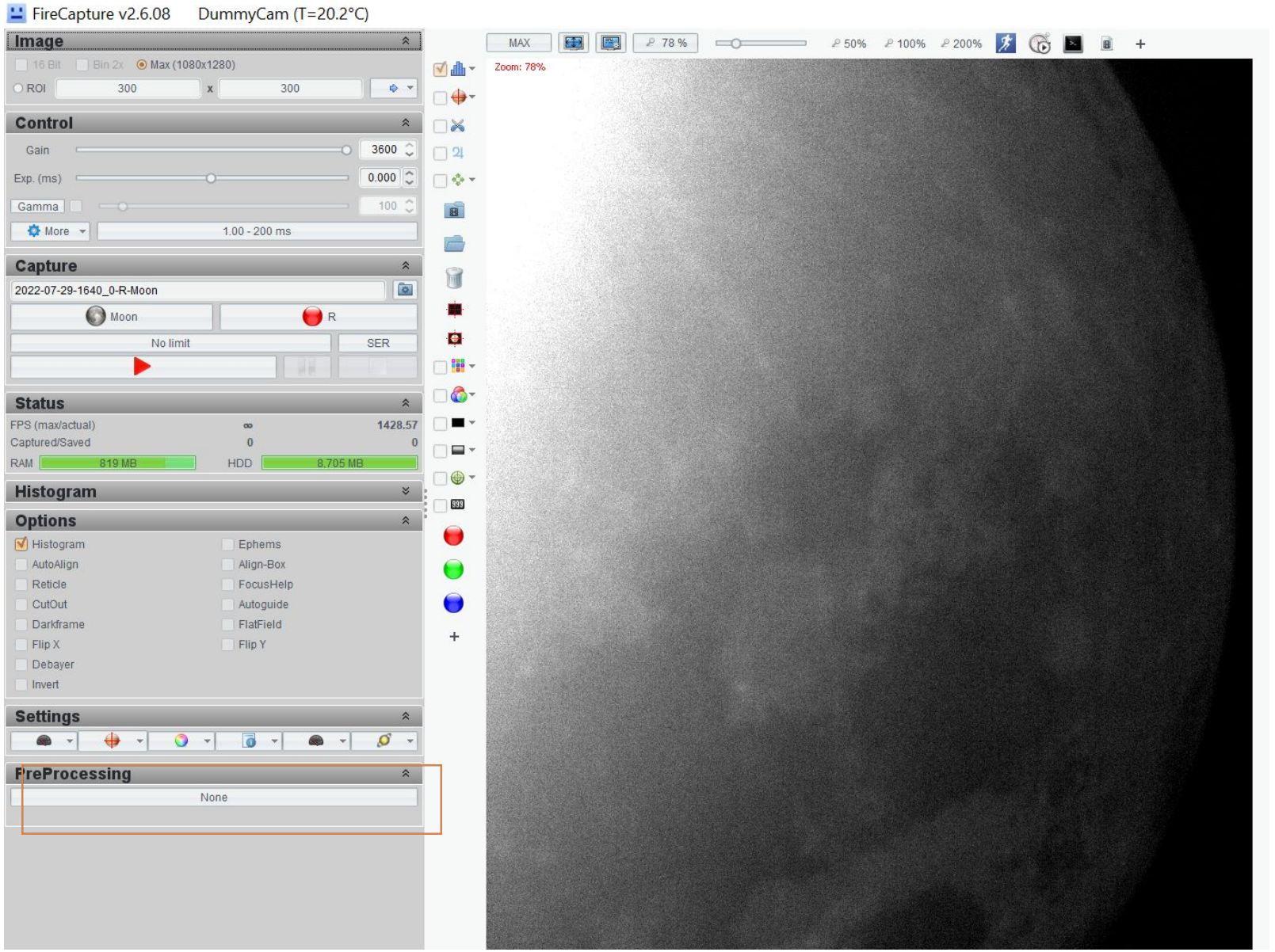
Observation and Online Detection Domain



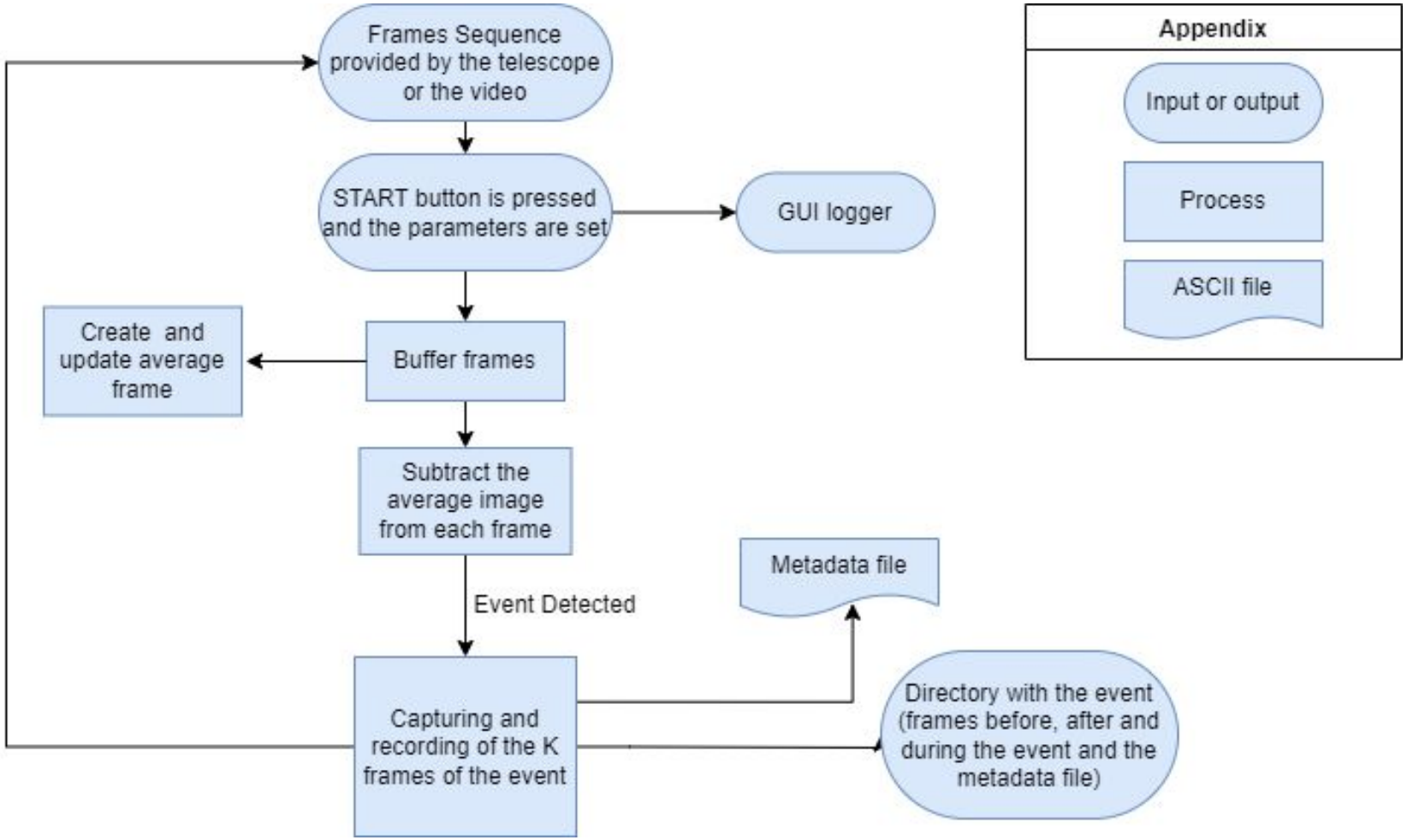
Observation and Online Detection Domain

- Observation and Online Detection Domain is a plugin program inside FireCapture
- We can find it in the “Preprocessing” area press the “None” button



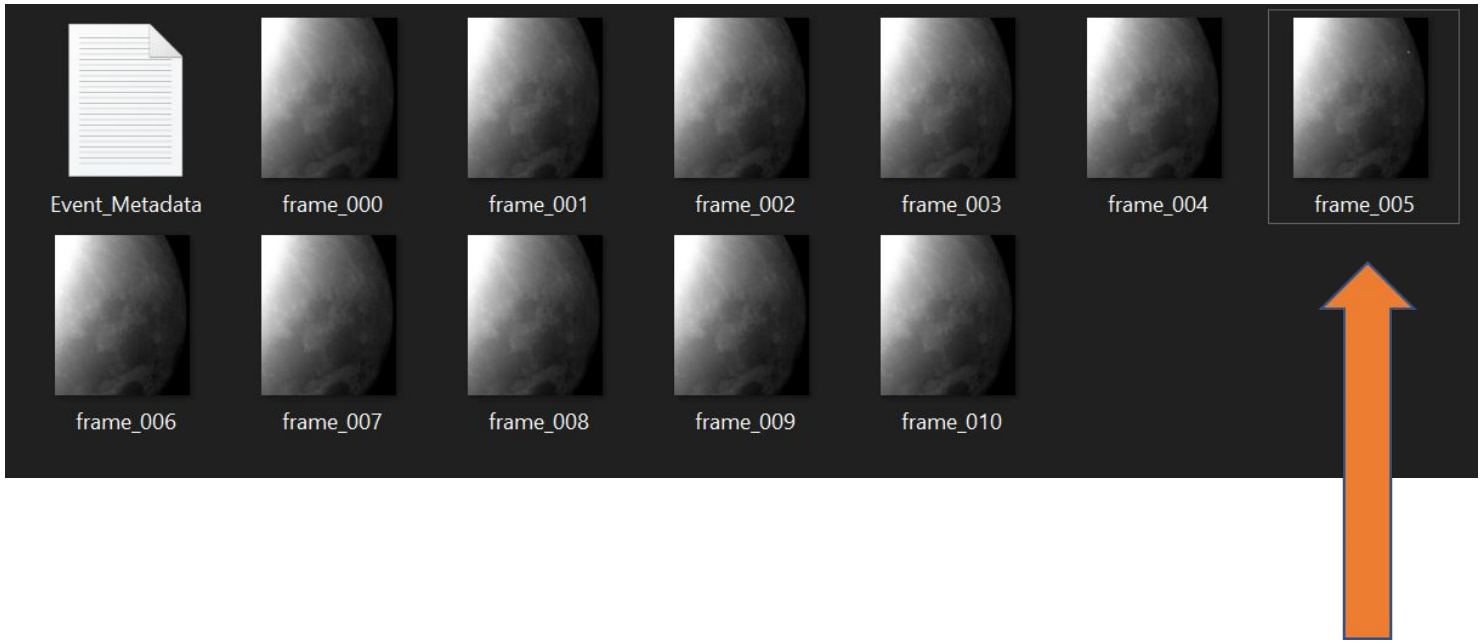


Online Detection Workflow



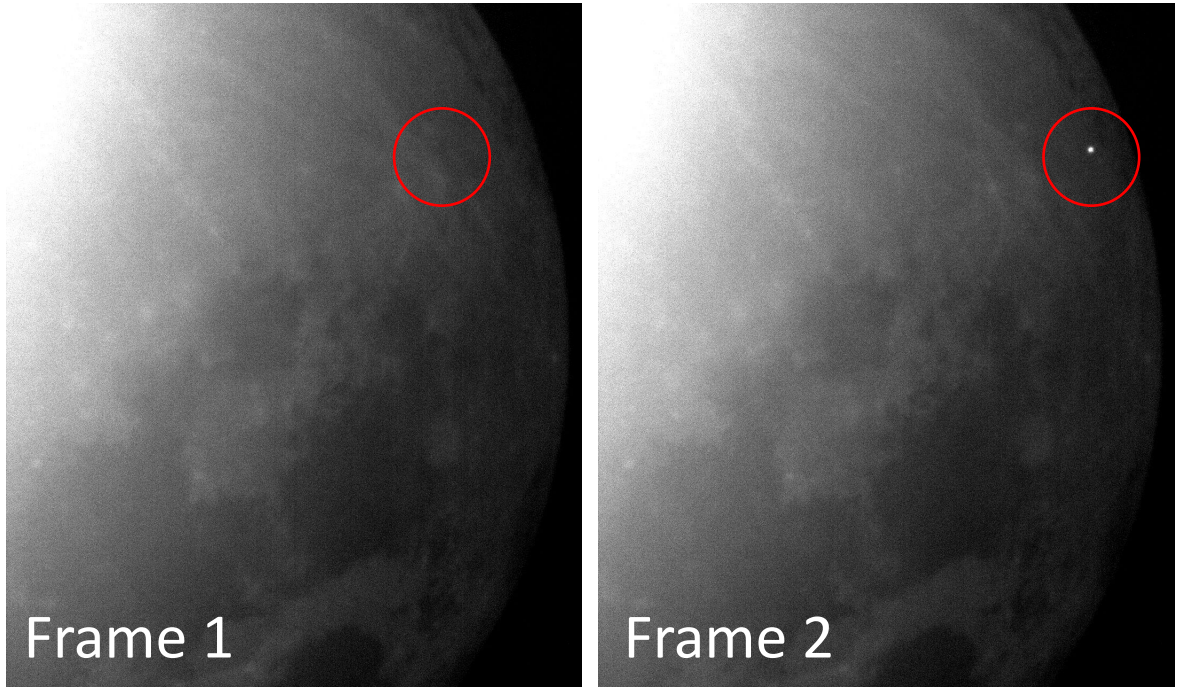
Online Detection - Results

- You will be notified by a logger that you have captured something
- Go to the “writing path” and check what is written
- You will have multiple events detected during the night, most of them will be cosmic ray

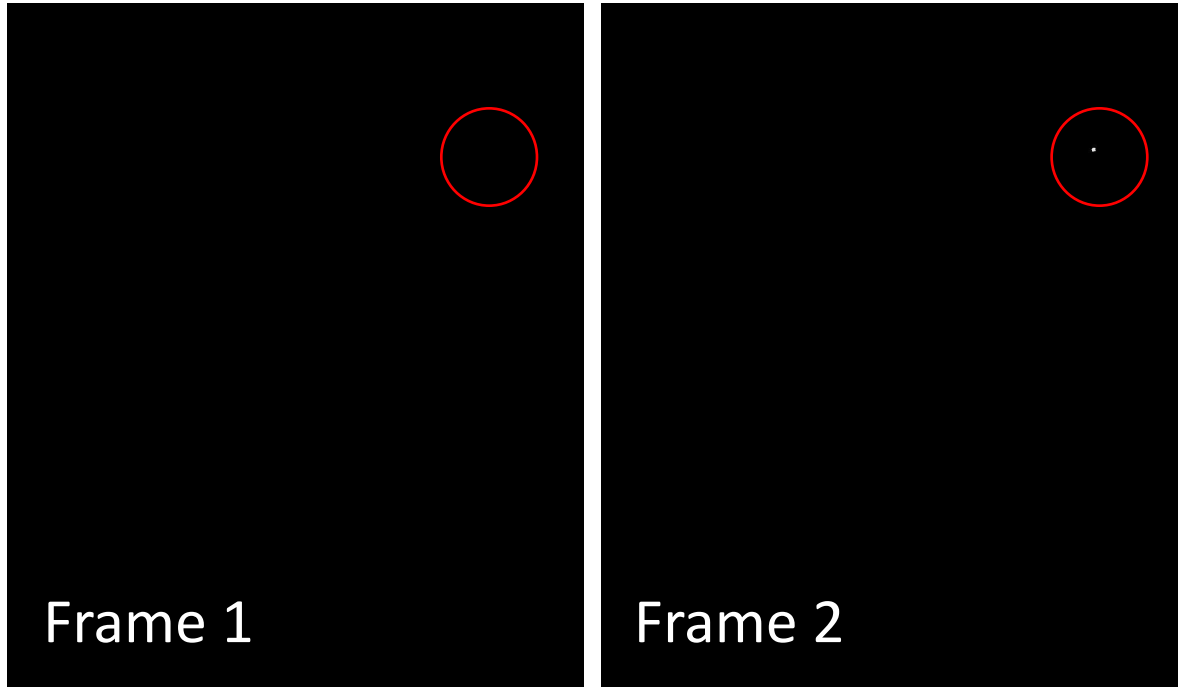


Online Detection Processing Phase

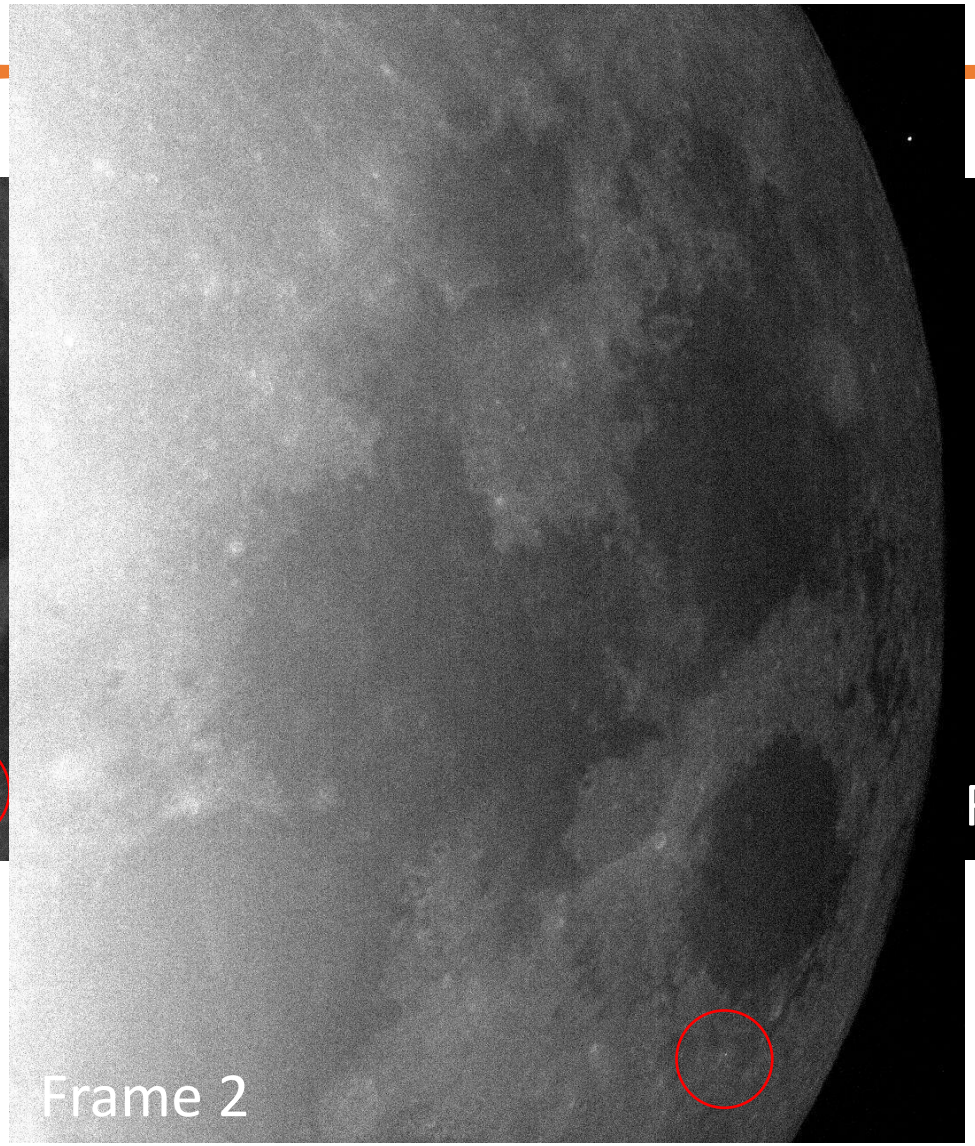
Before Processing



After Processing

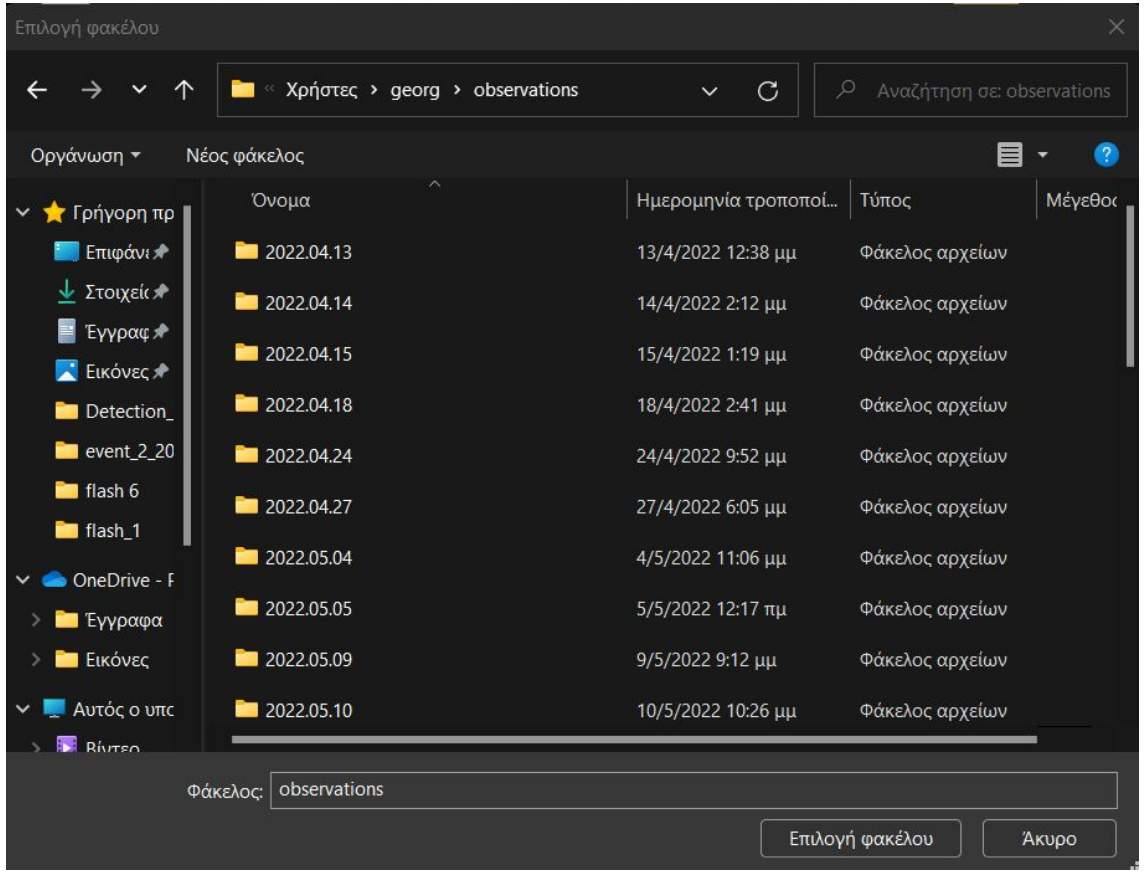


Online Detection Examples



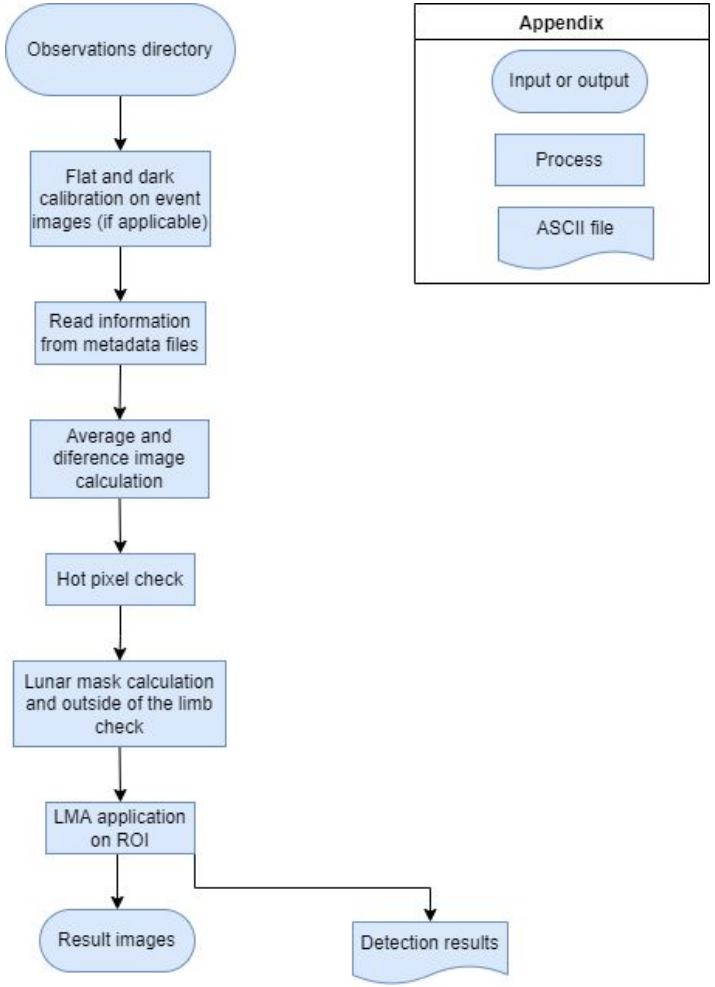
Offline Detection Domain - Motivation

- Each of the observation folders contains up to 50-200 events
- Offline detection will inform us quickly which of them could be impact flashes, and which of them are satellite, cosmic rays



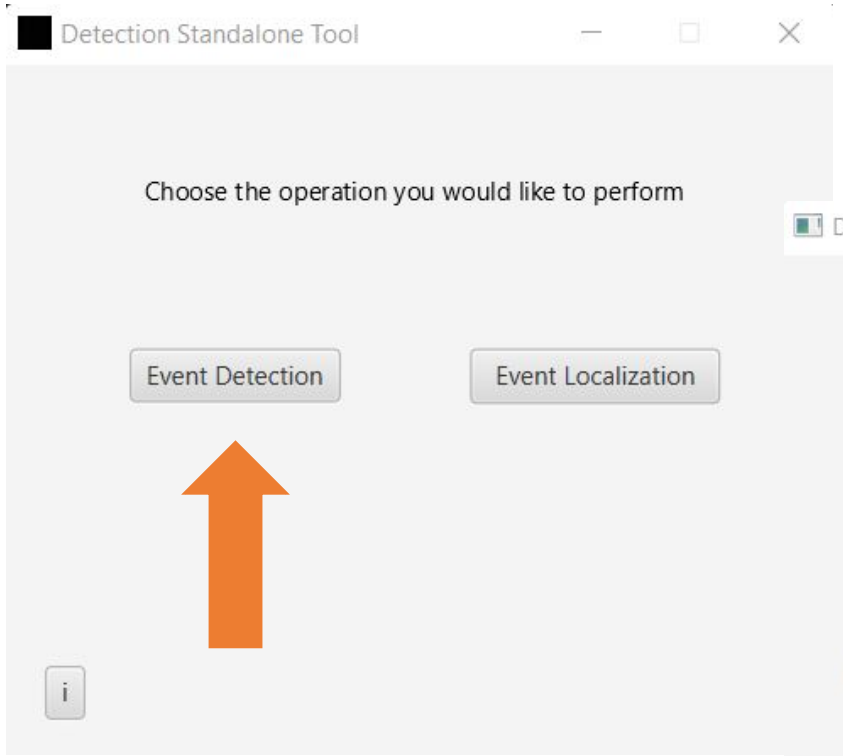
Offline Detection Domain - Workflow

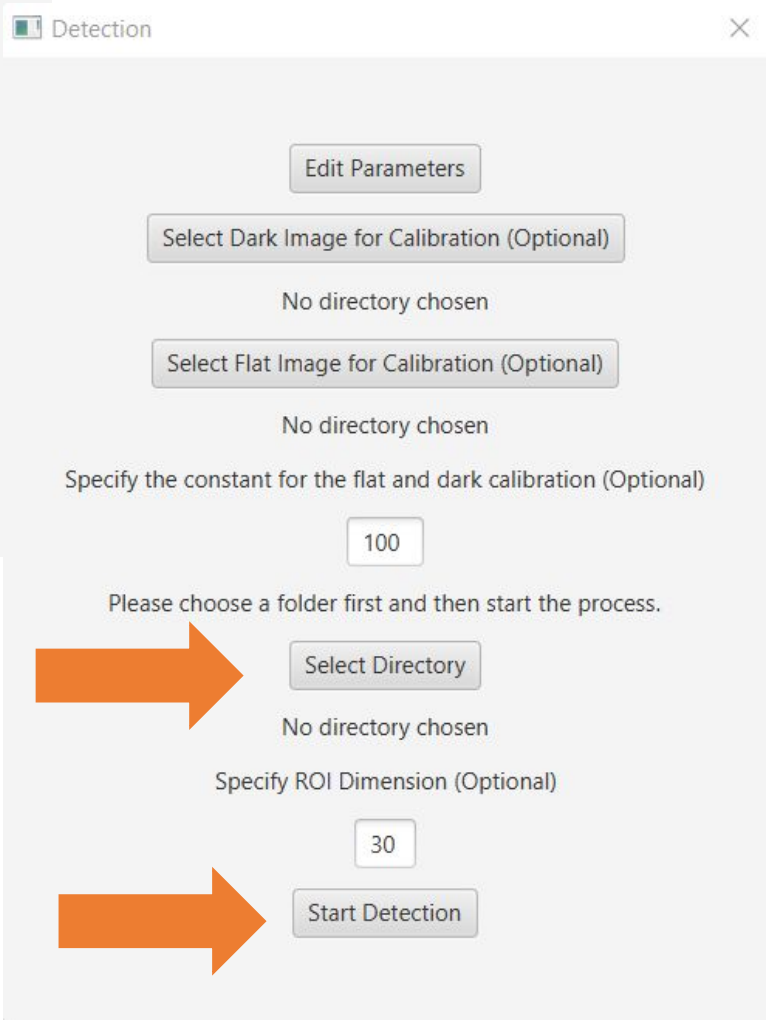
- For each event, the program will read some essential information from the metadata file
- Select a Region of Interest around the event
- Perform **Levenberg–Marquardt algorithm** and fit a 2D Gaussian distribution on the event
- Depending on the characteristics of the Gaussian the program classifies the event



How to use

- Offline Detection could take the entire directory of the observations of the day, and not each event separately
- Just select the desired directory

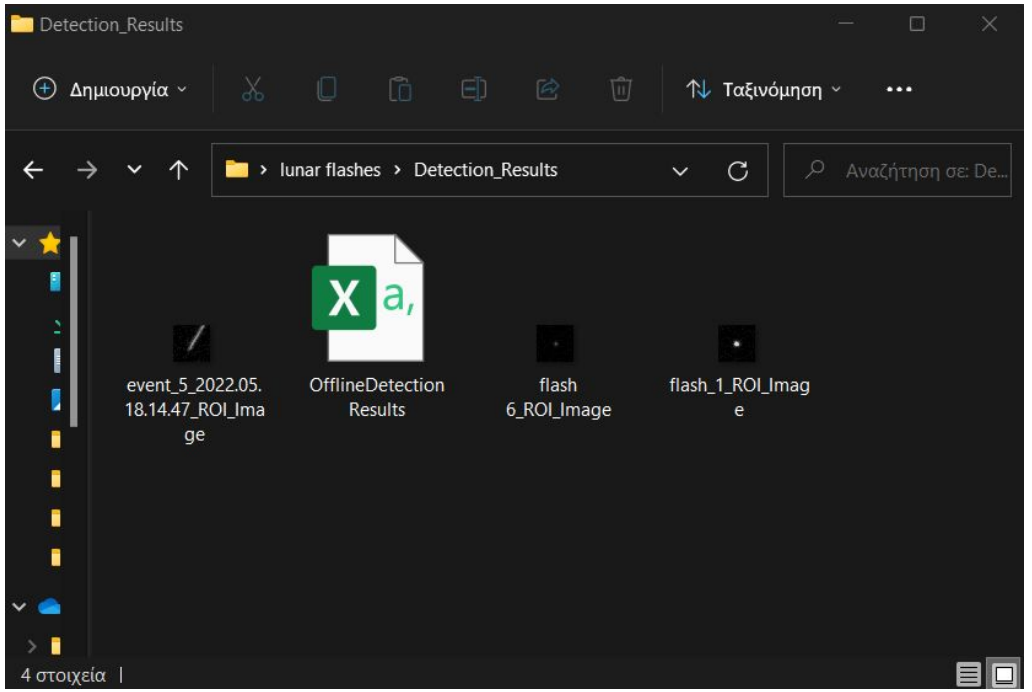




Offline Detection Domain - Results

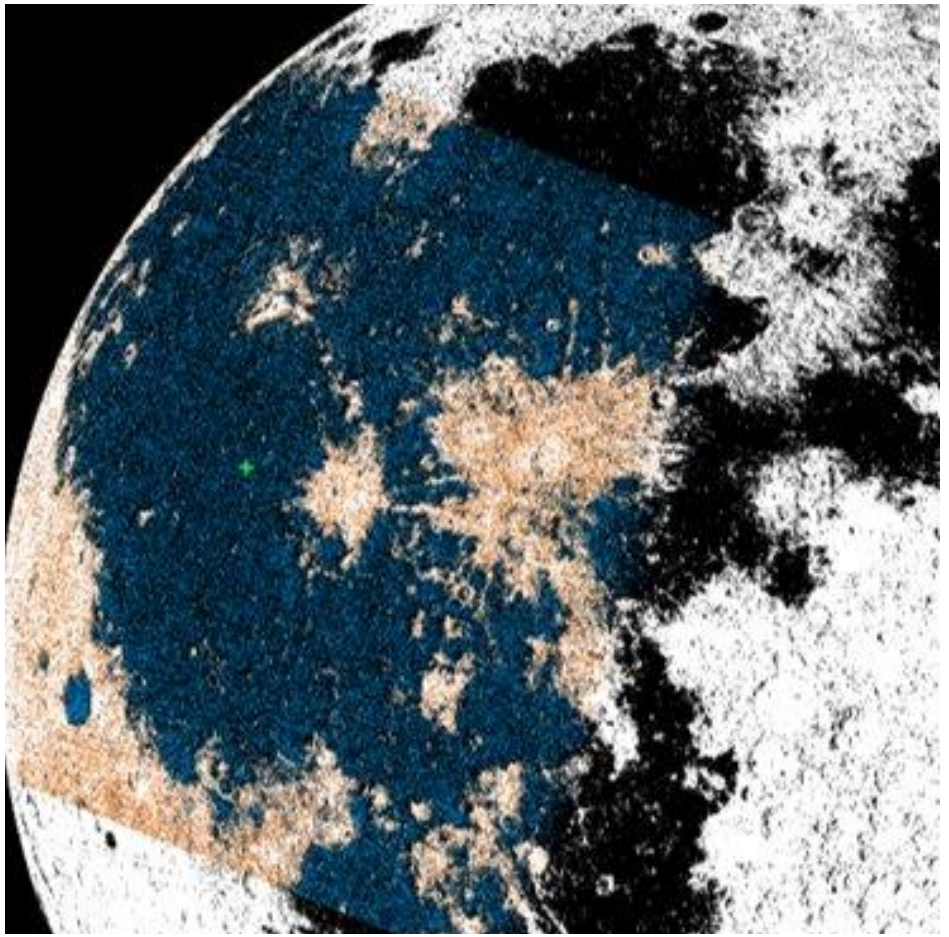
A	B	C	D	E	F	G	H	I	J	K	L	M
Event Directory Name	FWHM x	FWHM y	Impact Flash	Satellite	Hot Pixel	Cosmic Ray	Event outside of the limb	Result:				
flash_1	3,571	3,198	TRUE	FALSE	FALSE	FALSE	FALSE	Impact flash detected. (Coordinates: 1006, 721).				
flash 6	2,255	2,453	TRUE	FALSE	FALSE	FALSE	FALSE	Impact flash detected. (Coordinates: 410, 235).				
event_5_2022.05.18.14.4	2,399	22,761	FALSE	TRUE	FALSE	FALSE	FALSE	Satellite detected. (Coordinates: 747, 302).				

- In the working directory, you will find a csv file which has the classification of each event
- You can find more information

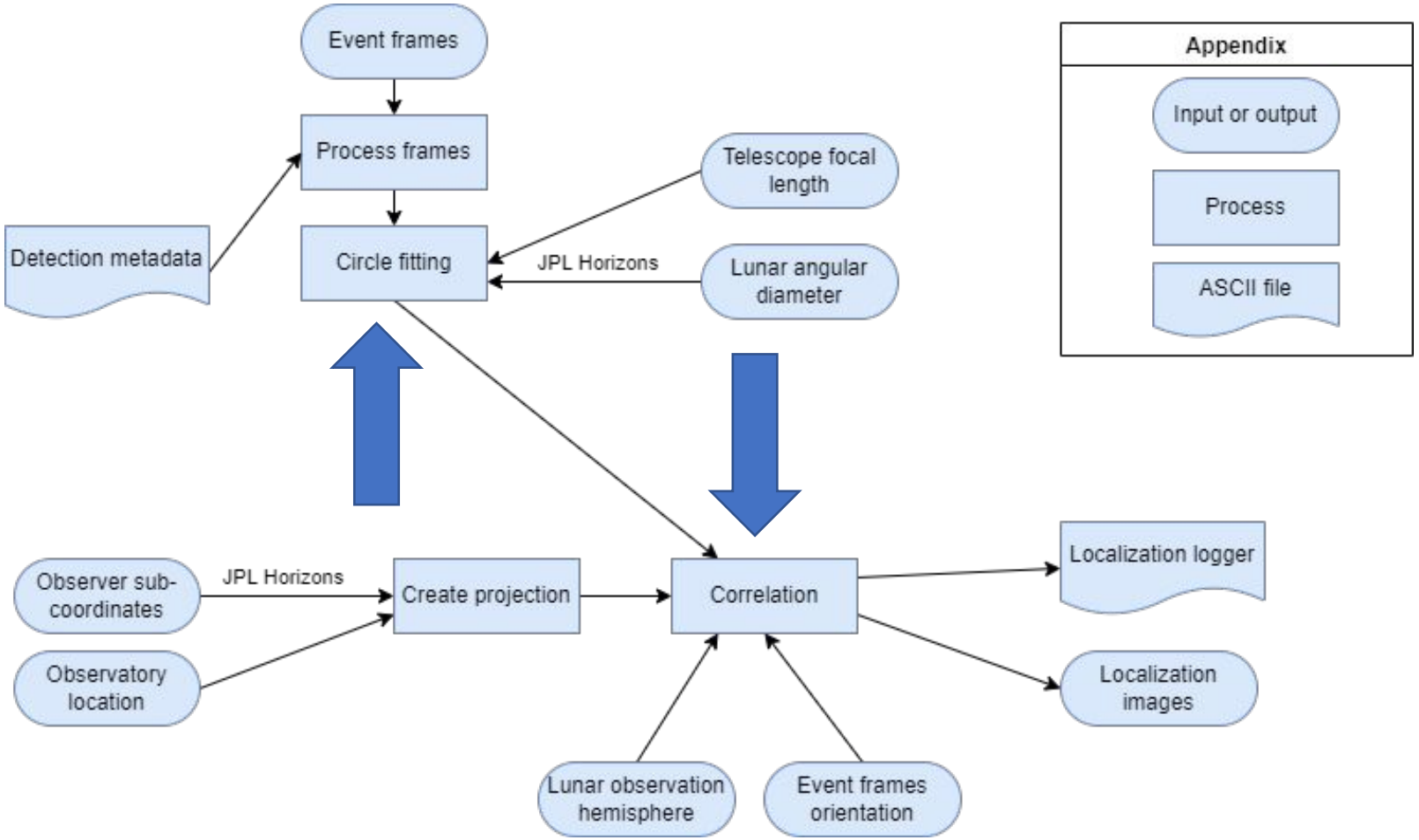


Localization - Motivation

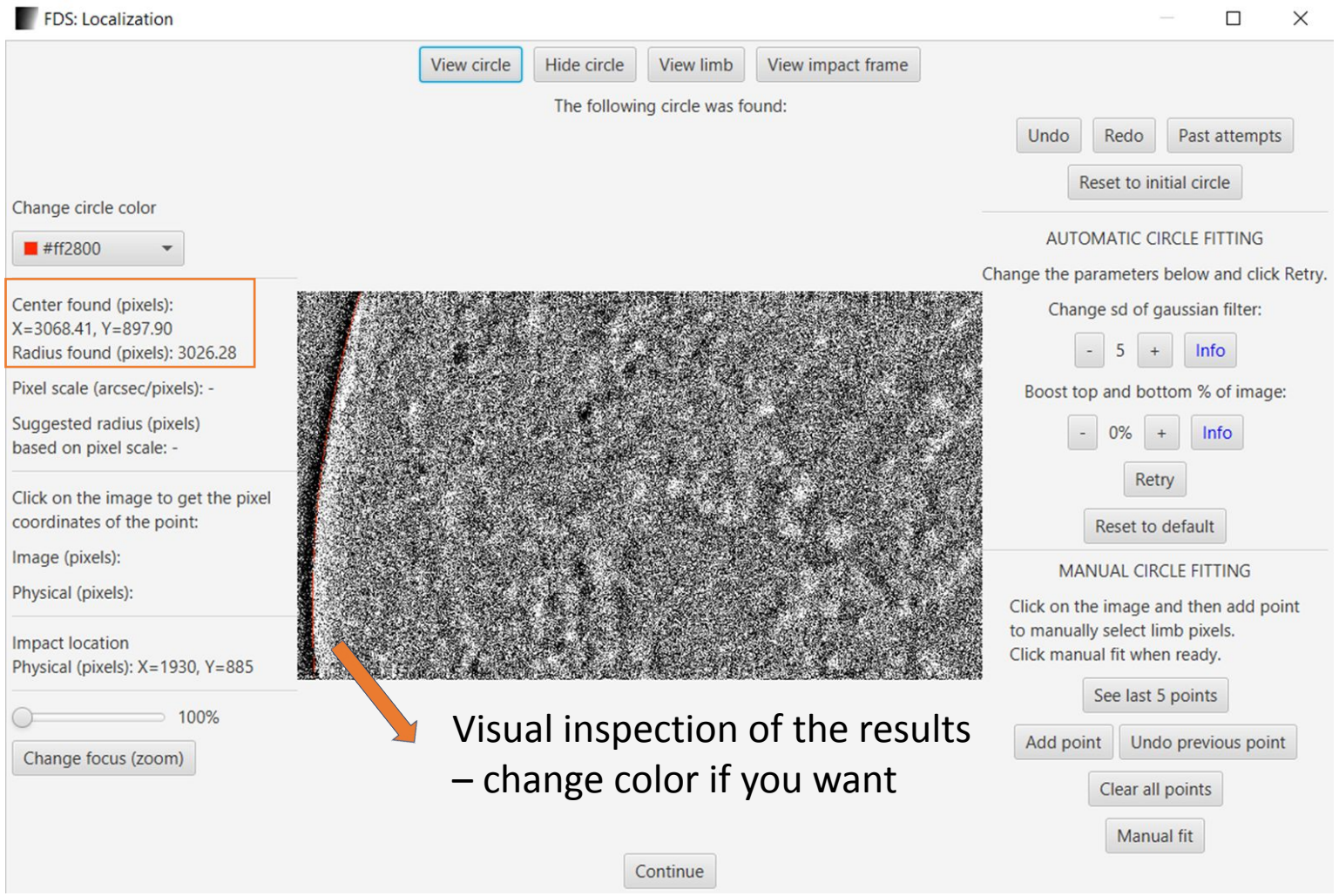
- Find the Selenographic Coordinate of the impact flash
- The methodology is based on the work of Avdellidou et al. 2021



Localization - Workflow



Results of automatically circle fitting



The results

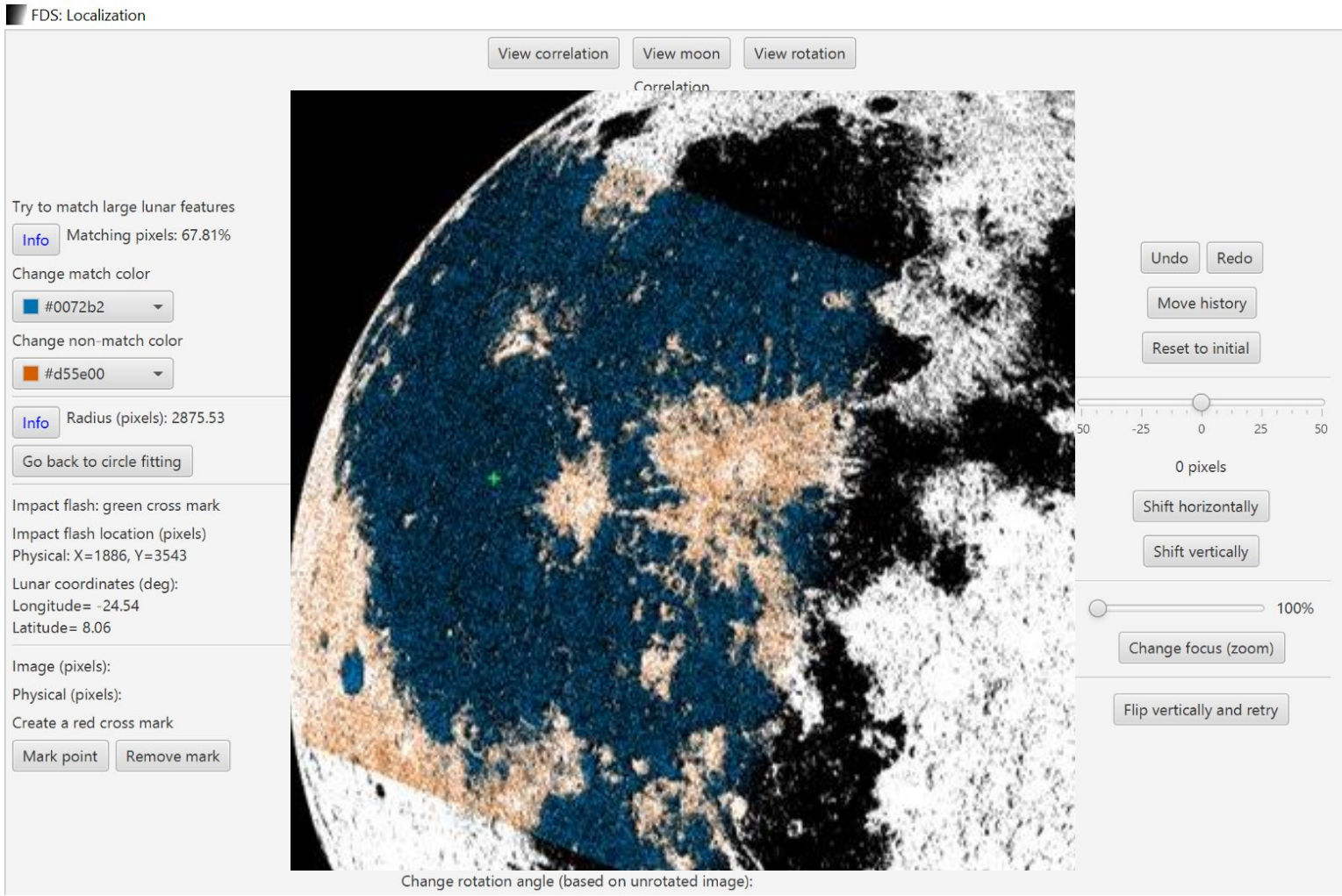
These results are empty because no focal length was given

Location of the event

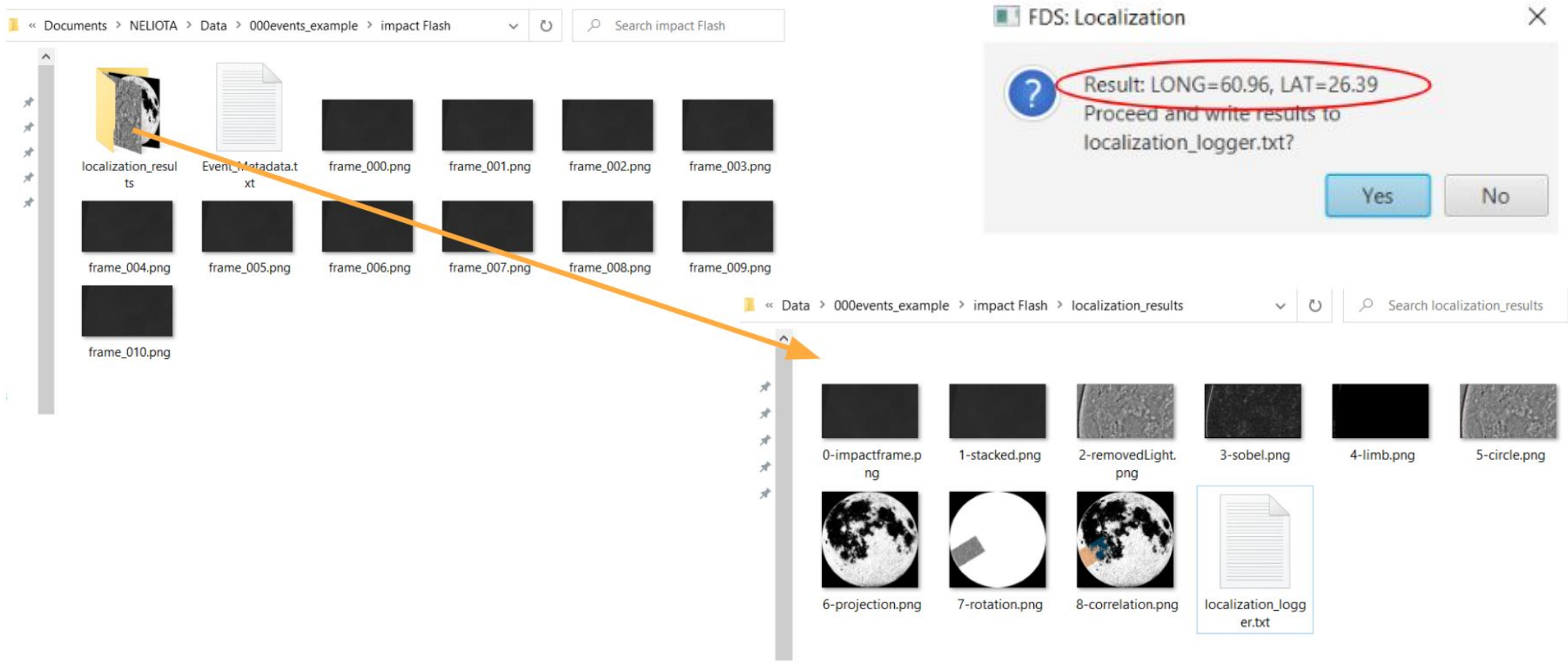
Visual inspection of the results – change color if you want

Automatic Correlation

- The image will be rotated so most of the points of our input image will fit in the binary lunar image
- This task could be performed manually too



Localization Results



Thanks for your attention