



# Flash Detection Software

## Theory Section

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

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## More impact flashes caught on camera

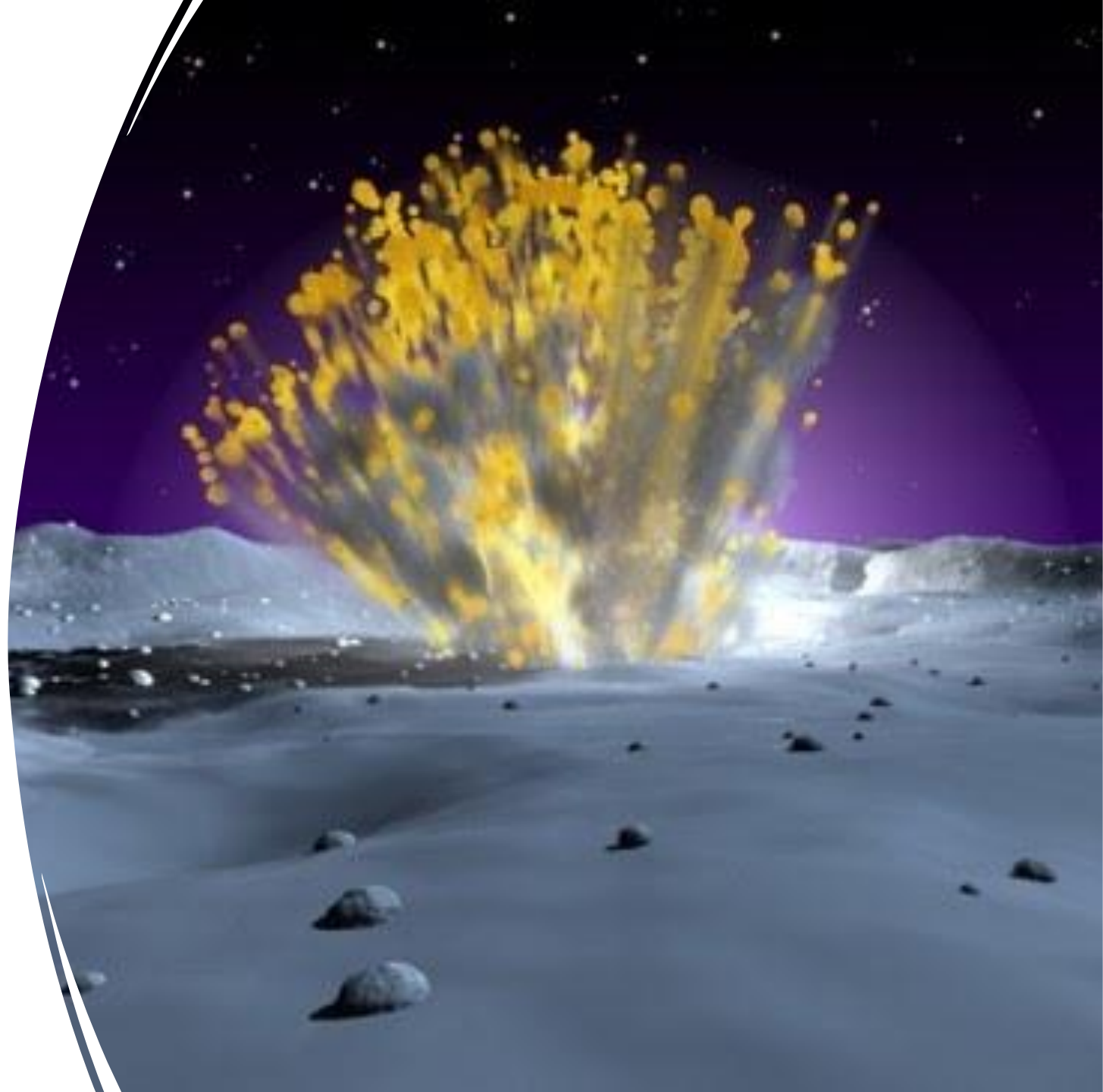
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- Moon is bombarded sporadically with a rate of **7.5 met/hr**, while Earth with a rate of  $\sim 100$  met/h (mesosphere meteors) and with a rate of  $\sim 175$  met/h at LEO
- Observe Moon for impact flashes at 0.1-0.45 lunar phases  $\sim 5-8$ 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

Suggs et al. (2012):  $1.03 \times 10^{-7}$  flash/hr/km<sup>2</sup>

Rembold & Ryan (2015):  $1.09 \times 10^{-7}$  flash/hr/km<sup>2</sup>

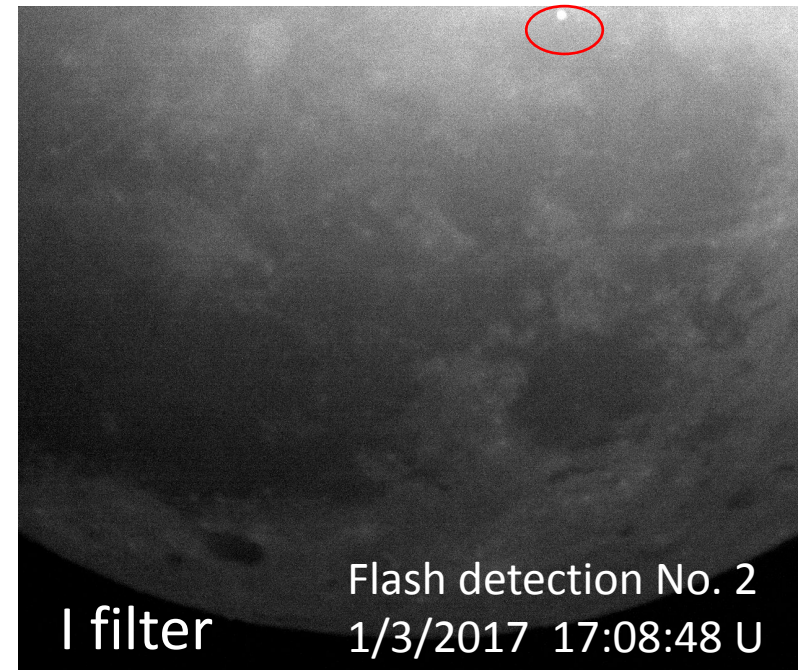
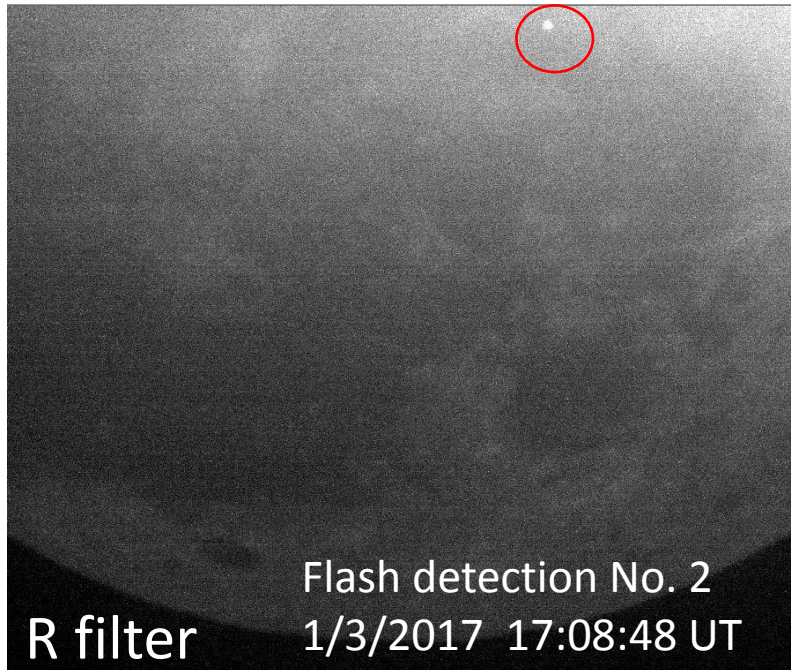
NELIOTA:  $2.30 \times 10^{-7}$  flash/hr/km<sup>2</sup>



# Cross-validation of impact events across users

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



# True Impact Flash

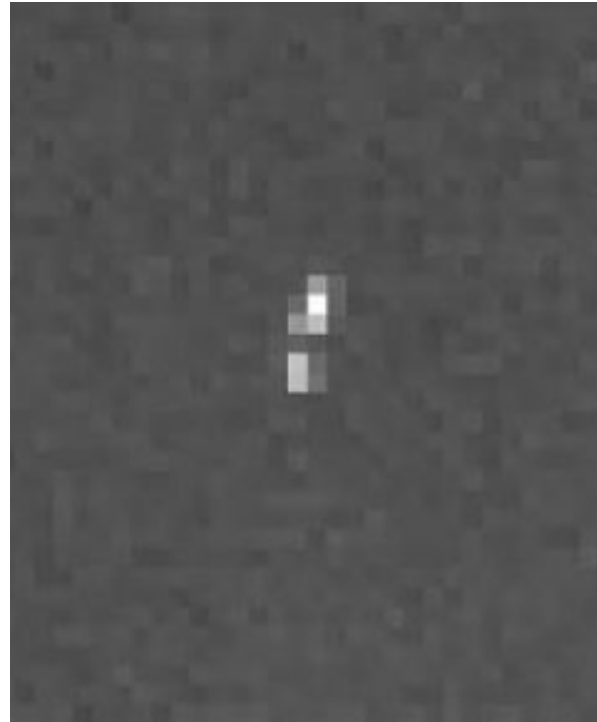
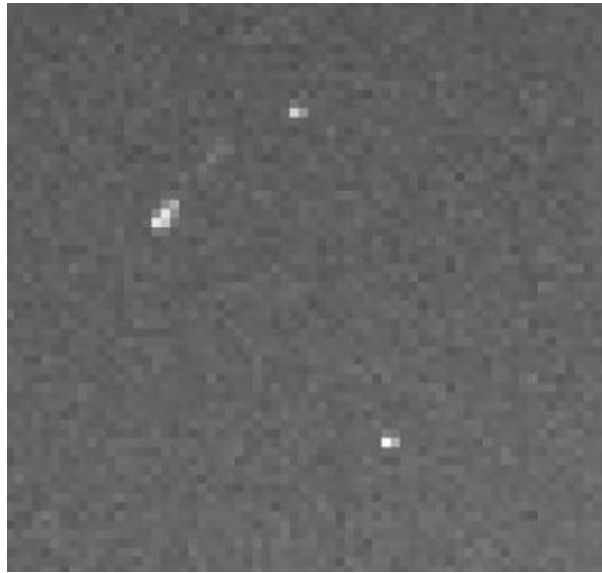
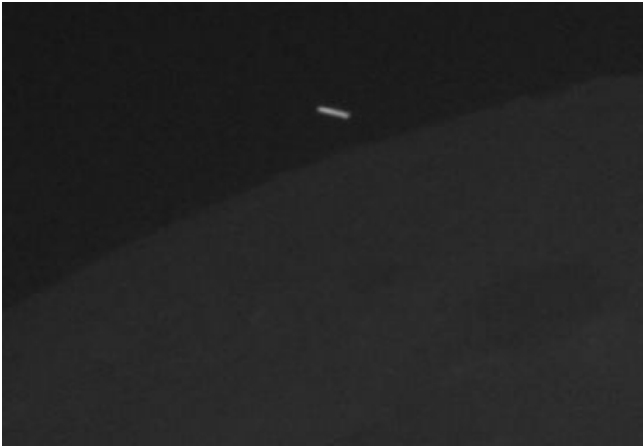
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- 2 frames in R
- 4 frames in I
- R= 6.7 mag
- I= 6.0 mag



# False Impact Flashes

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# More observation hours!

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- Non-sunlit side
- Observation area:  $3 \times 10^6 \text{ km}^2$   
(in NELIOTA System Setting)



# Challenges of an open-source tool for amateurs astronomers

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## Many different Cameras and Telescopes

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- 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**

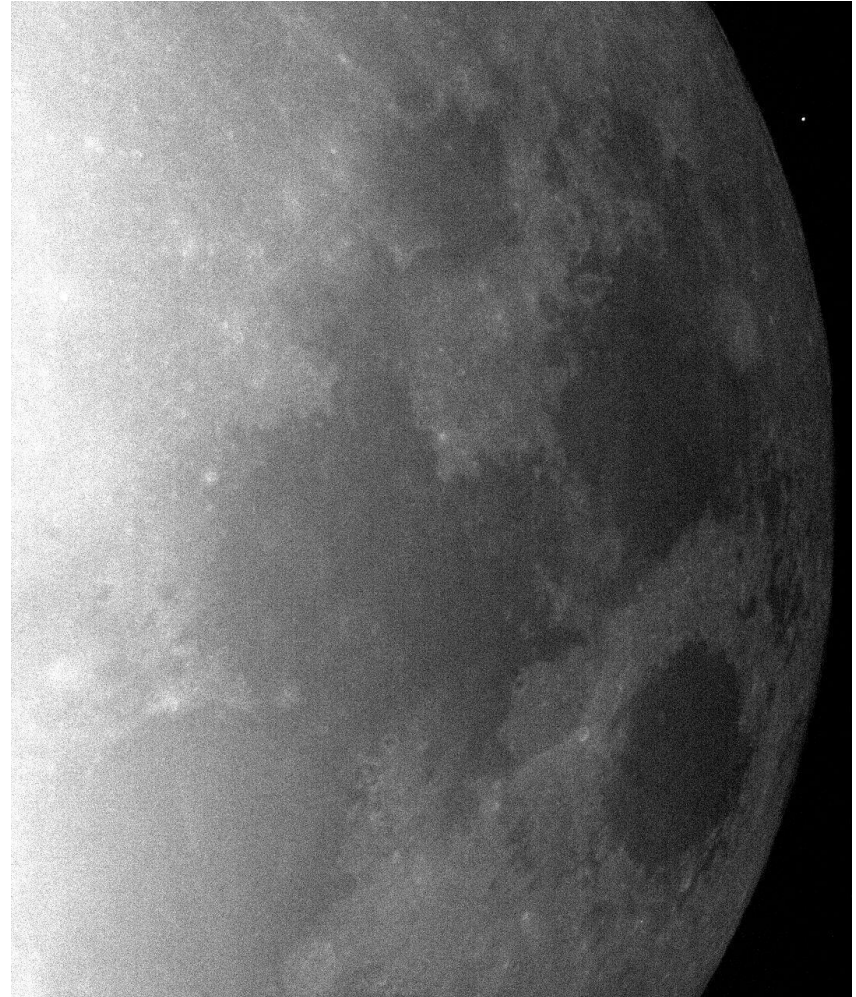
- 194.04 hrs Lunar observation
- 152.75TB of data

# Optimal observations of the moon

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What is an optimal observation?

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



# Non-Optimal observations of the moon

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- ∅ Include sunlit side (saturation)
- ∅ Phases above  $\sim 0.5$  (straylight)
- ∅ Air pollution and clouds
- ∅ Observations below  $\sim 20$  deg

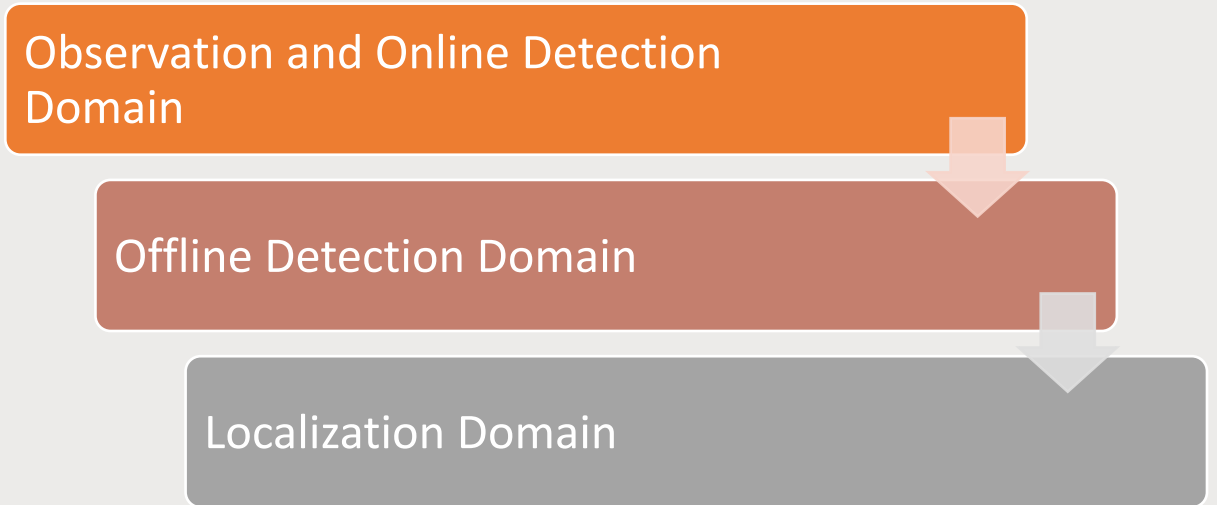


# The open-source tool for lunar impact flash detection

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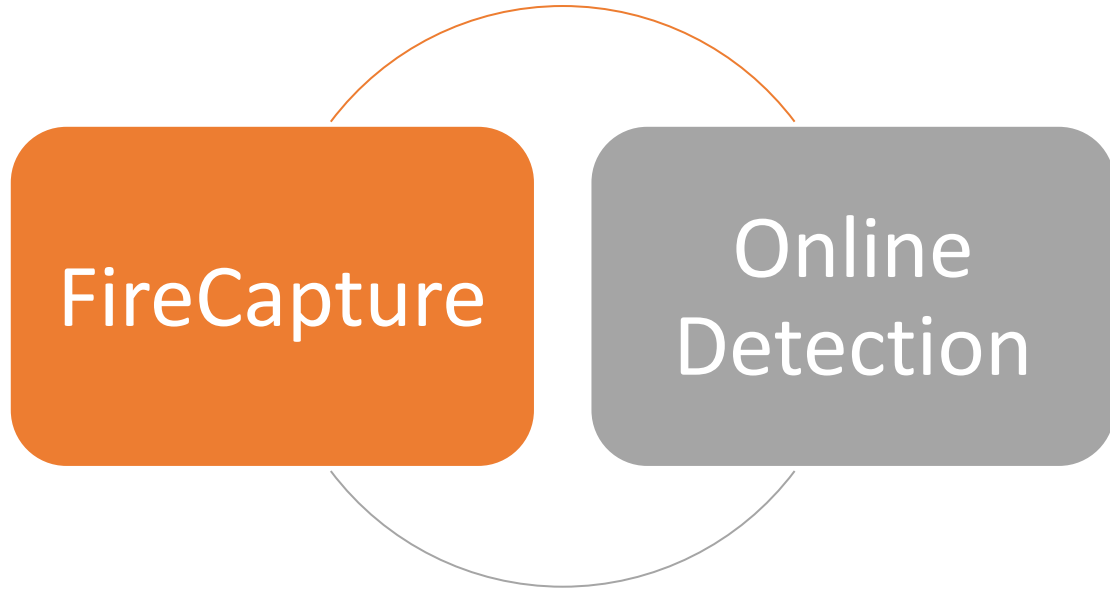


# Structure of the Tool



# Observation and Online Detection Domain

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# 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

PreProcessing & Plugins

Reset all Filter / Plugins

ON / OFF	Visible	Filter / Plugin
✗		Contrast
✗		Live-Stacking
✗		Average
✗		Mosaic-Helper
		Color-Saturation
✗		Bright Object
✗		Moving Object (daytime)
✗		Moving Object (night)
✗		Planetary mask
✗		FDS v0.09.1
✓	✓	FDS v0.09.1
✗		Planetary mask

FireCapture v2.6.08 DummyCam (T=20.2°C)

**Image**  
16 Bit Bin 2x Max (1080x1280)  
ROI 300 x 300

**Control**  
Gain 3600  
Exp. (ms) 0.000  
Gamma 100  
More 1.00 - 200 ms

**Capture**  
2022-07-29-1640\_0-R-Moon  
Moon R  
No limit SER

**Status**  
FPS (max/actual) ∞ 1428.57  
Captured/Saved 0 0  
RAM 819 MB HDD 8.705 MB

**Histogram**

**Options**  
Histogram [checked] Ephems [unchecked]  
AutoAlign [unchecked] Align-Box [unchecked]  
Reticle [unchecked] FocusHelp [unchecked]  
CutOut [unchecked] Autoguide [unchecked]  
Darkframe [unchecked] FlatField [unchecked]  
Flip X [unchecked] Flip Y [unchecked]  
Debayer [unchecked]  
Invert [unchecked]

**Settings**

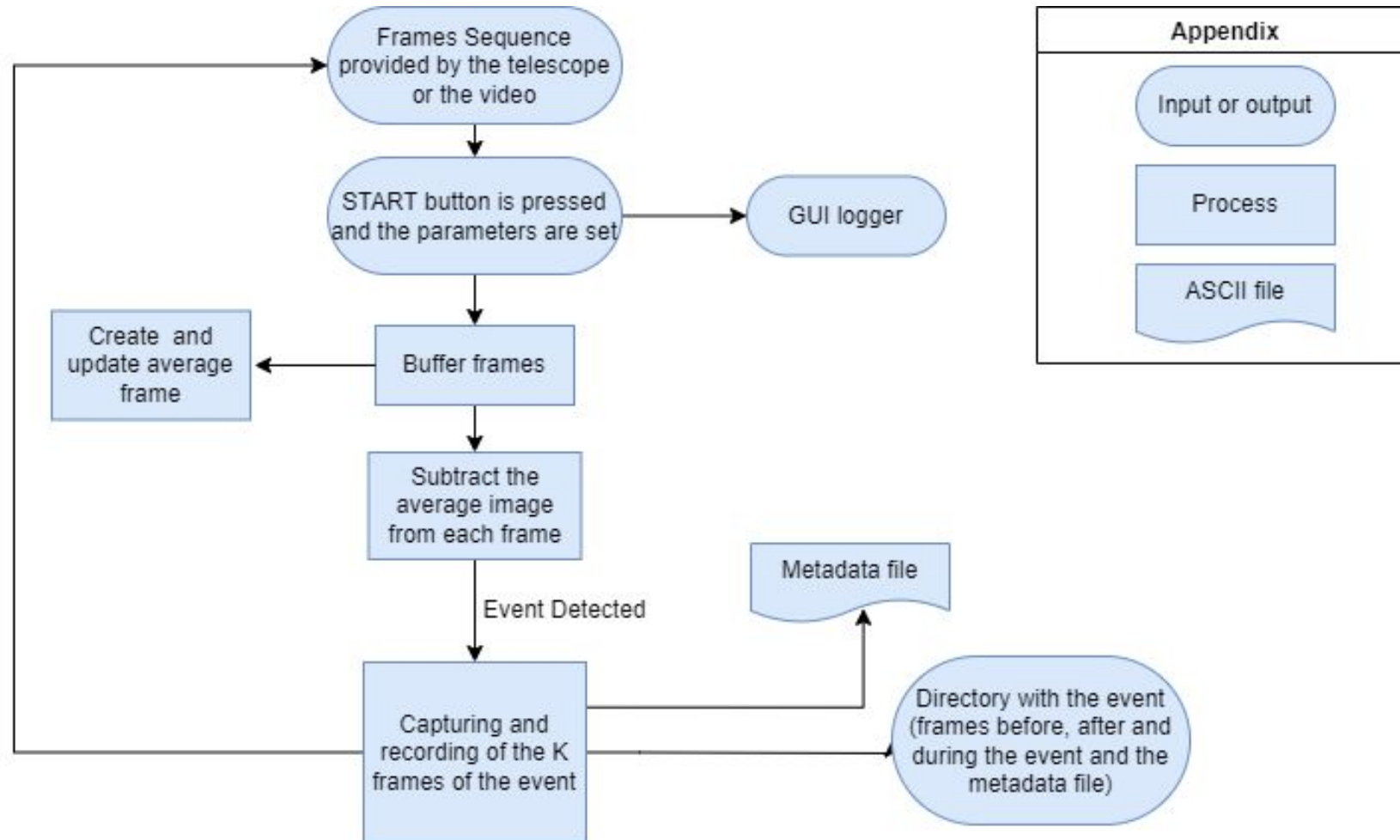
**PreProcessing**  
None

MAX 78% 50% 100% 200%

Zoom: 78%



# Online Detection Workflow



# Online Detection - Results

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- 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



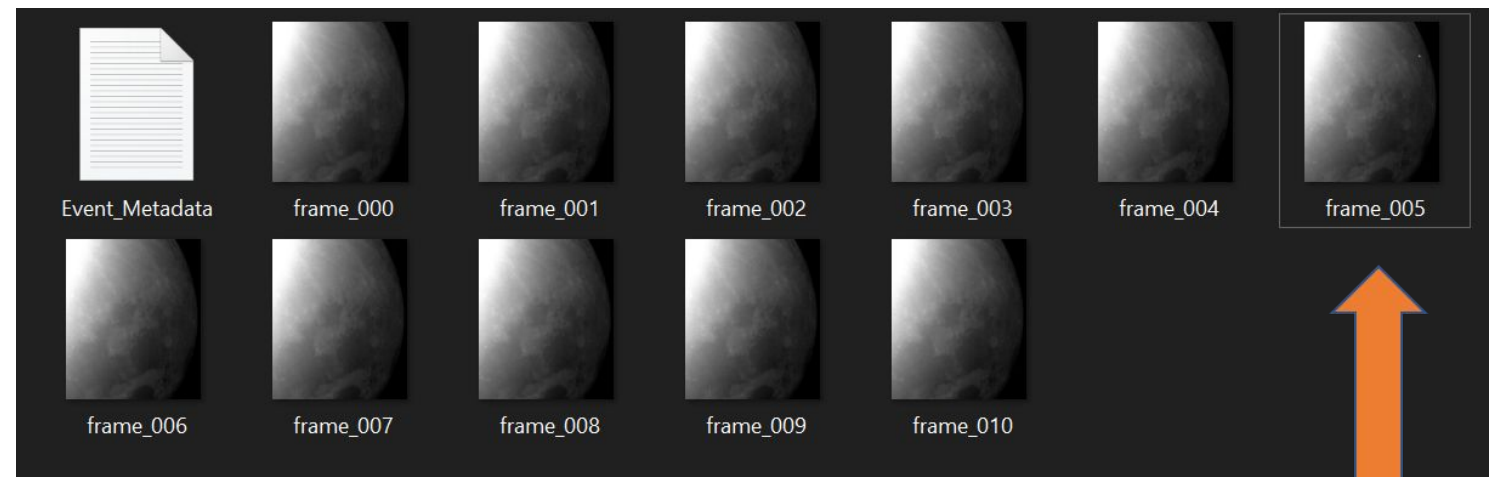
```
FDS Logger: FDS v0.09.1

The number of pixels of the event is: 46.

The writing process for the 5 captured event has ended.

Detection occurred. The writing process starts. This is the 6 captured event.
The event occurred at: 2022-08-09 08:13:14.967 (UTC).
The number of pixels of the event is: 46.

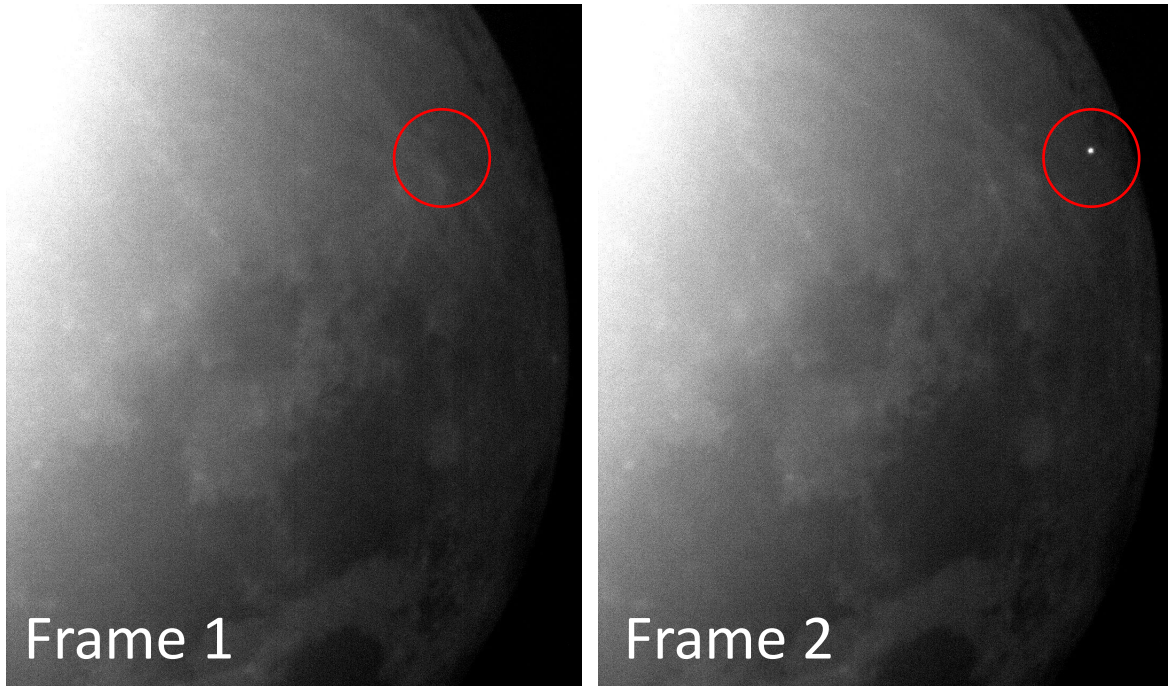
The writing process for the 6 captured event has ended.
```



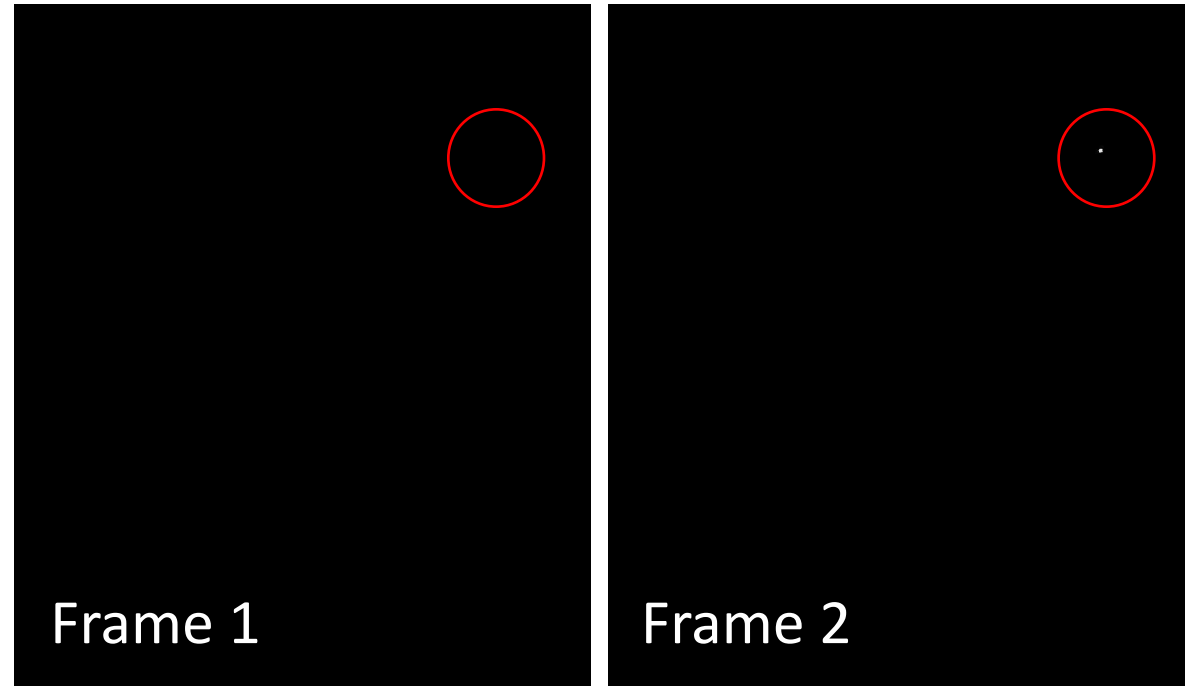
# Online Detection Processing Phase

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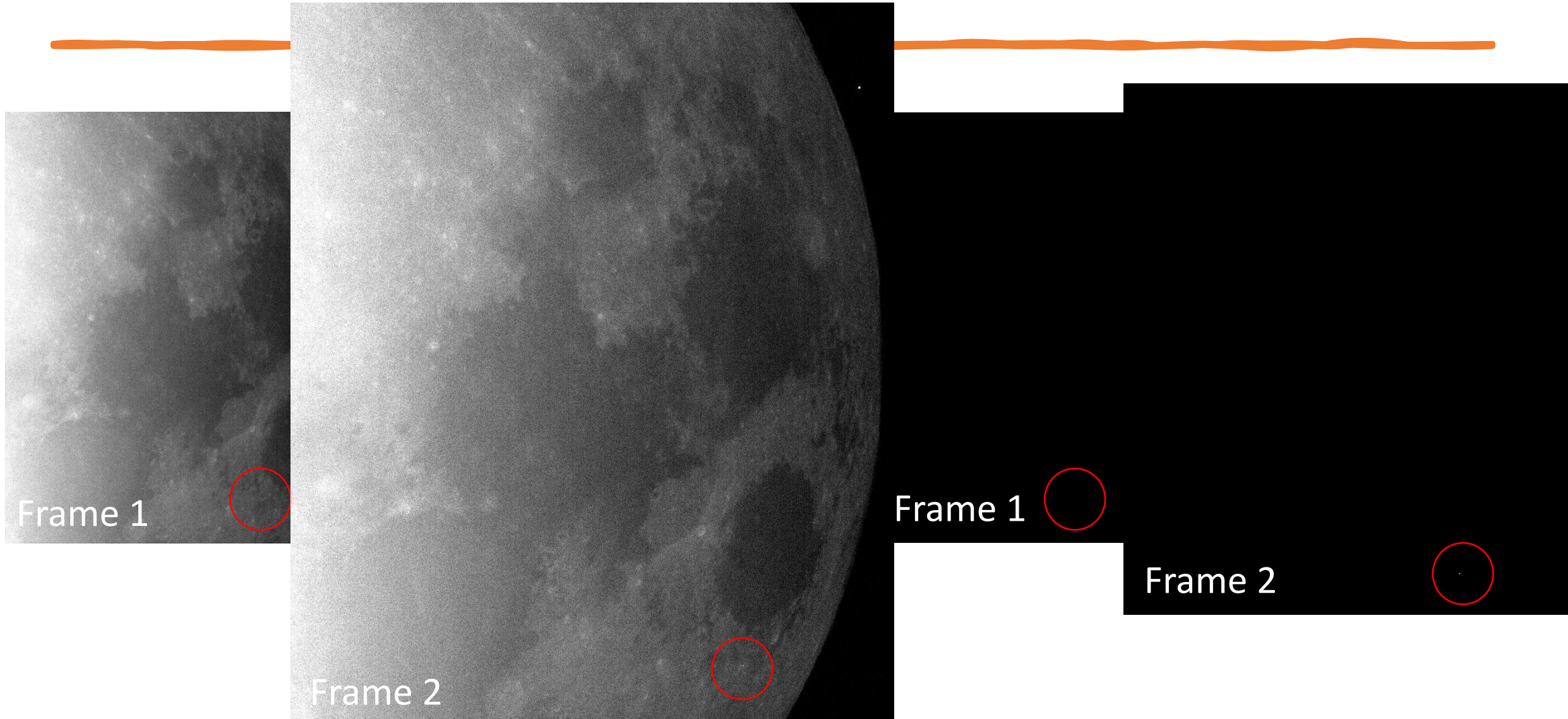
Before Processing



After Processing

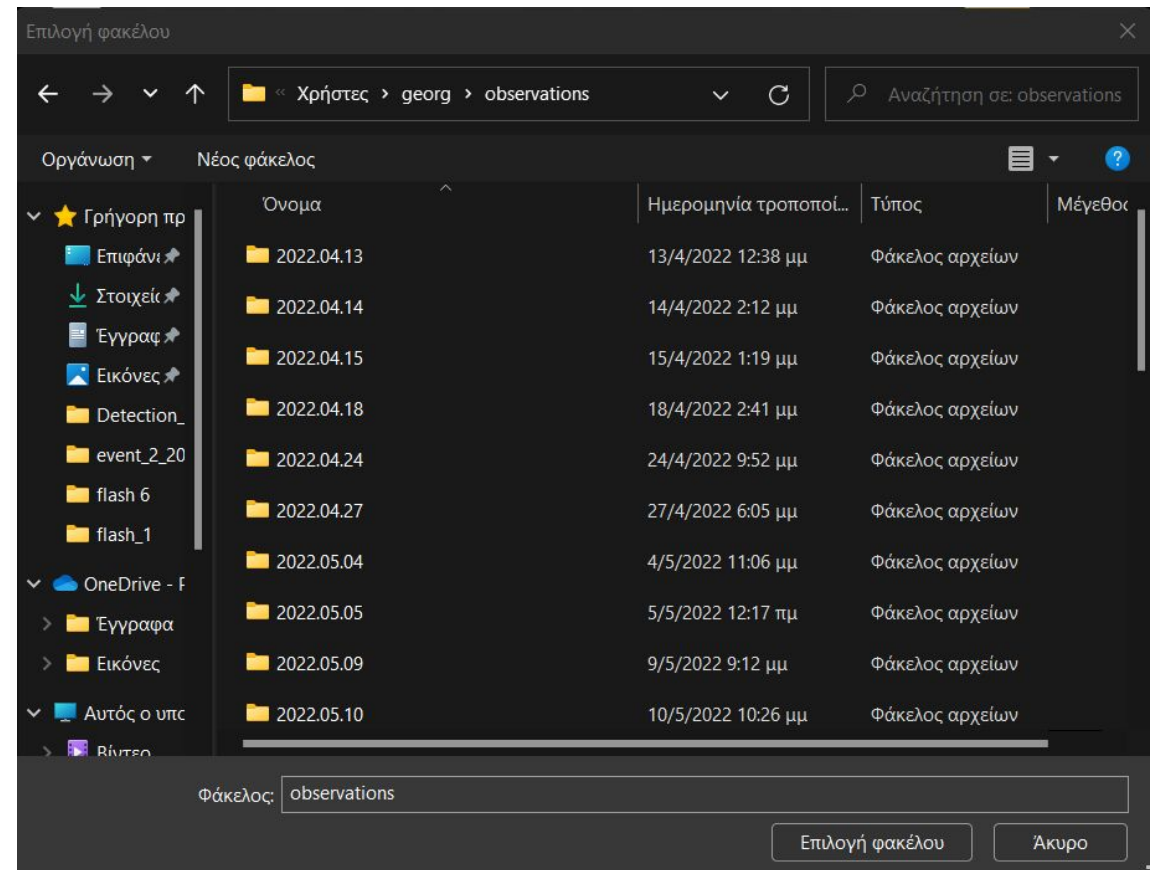


# Online Detection Examples



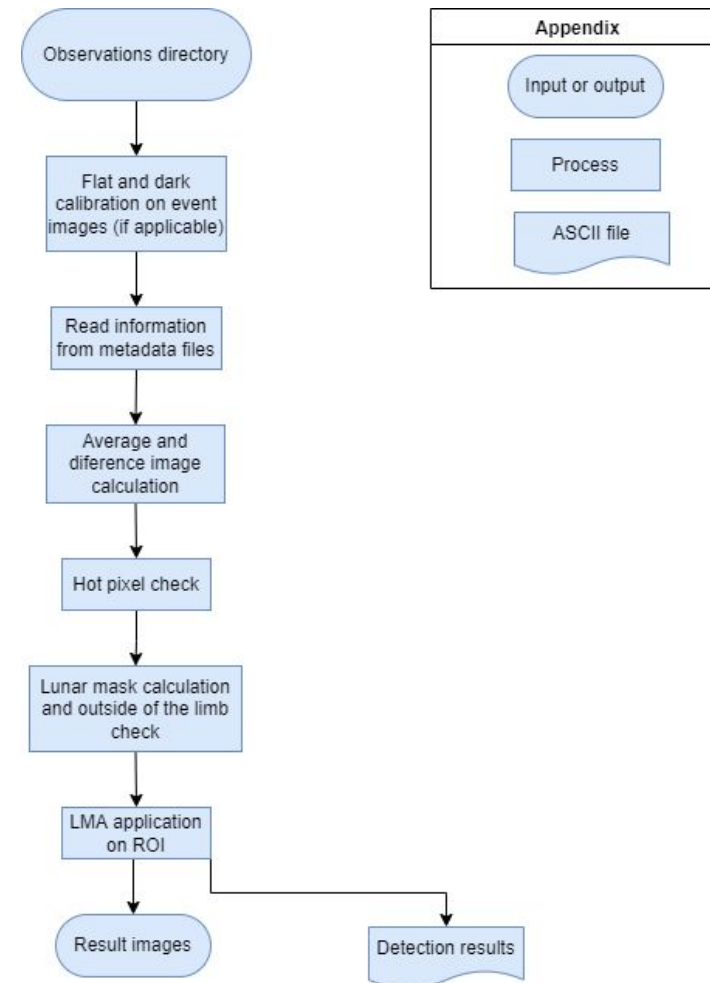
# Offline Detection Domain - Motivation

- ❖ 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



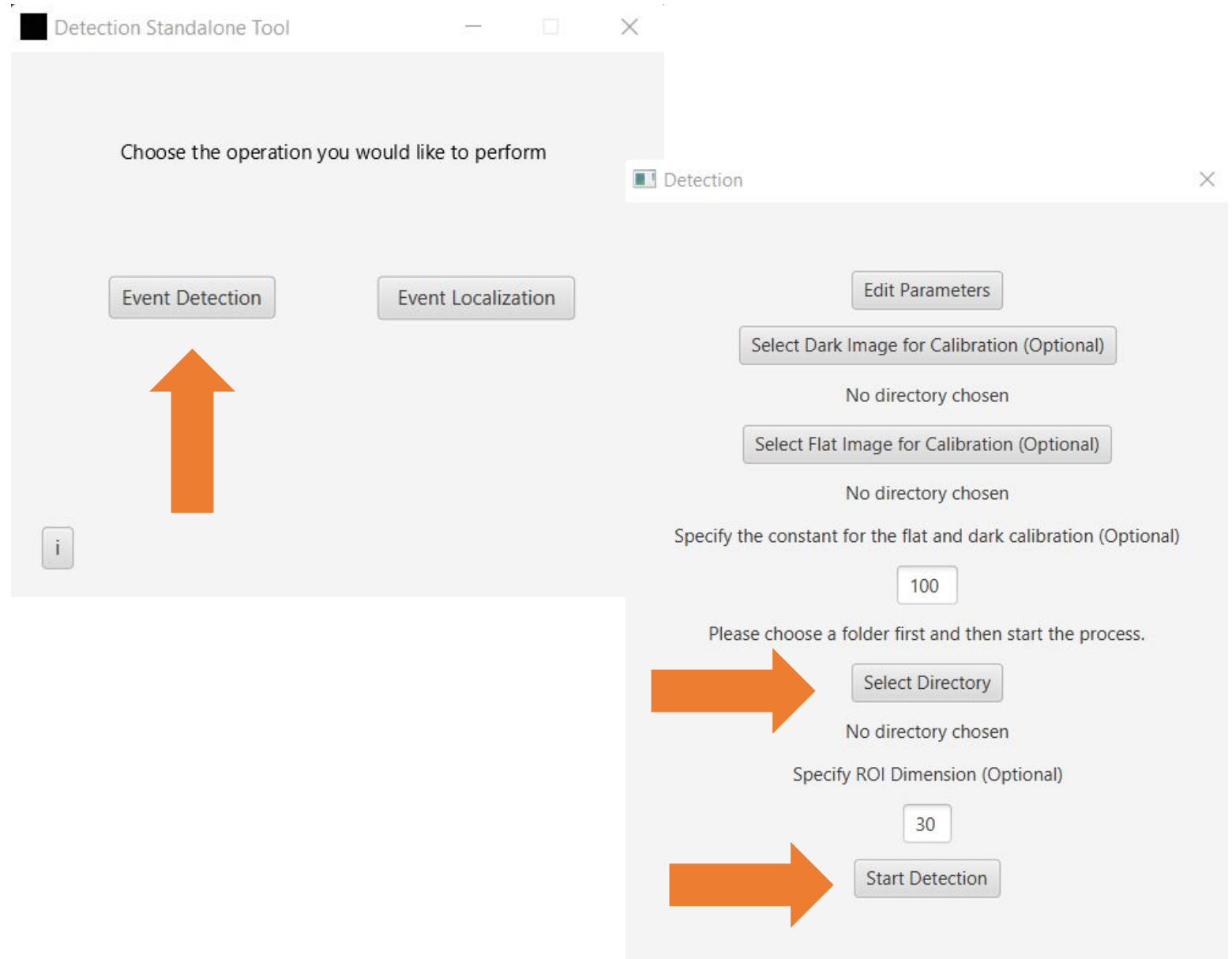
# Offline Detection Domain - Workflow

- 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

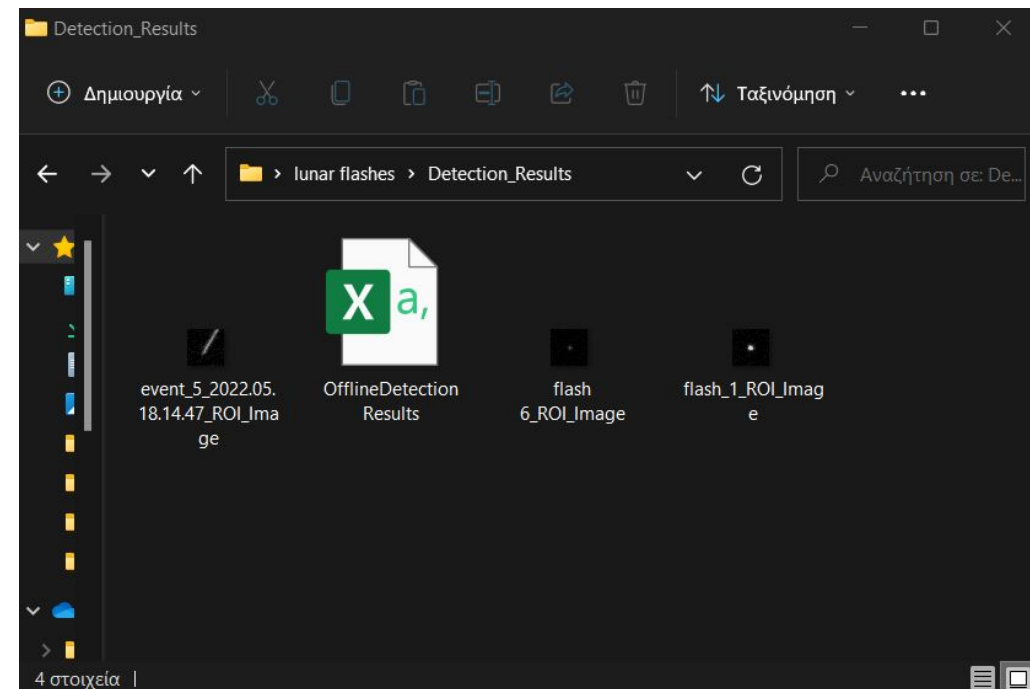
- Offline Detection could take the entire directory of the observations of the day, and not each event separately
- Just select the desired directory



# 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

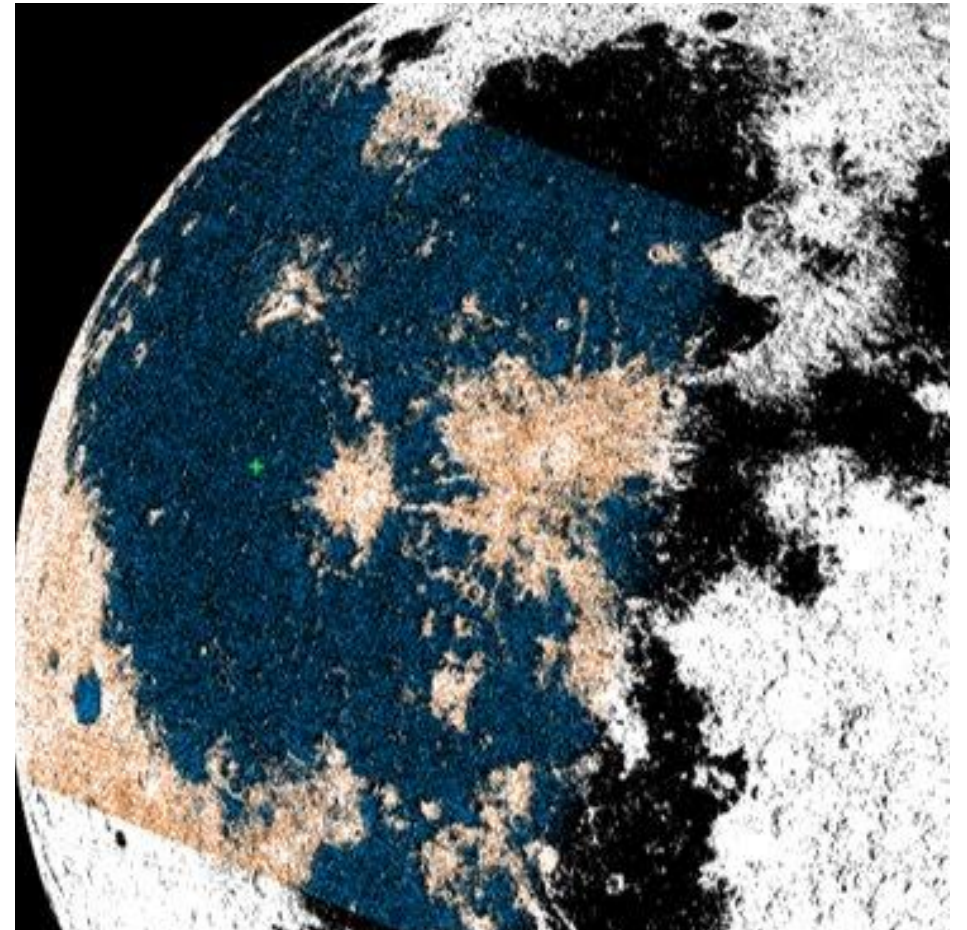




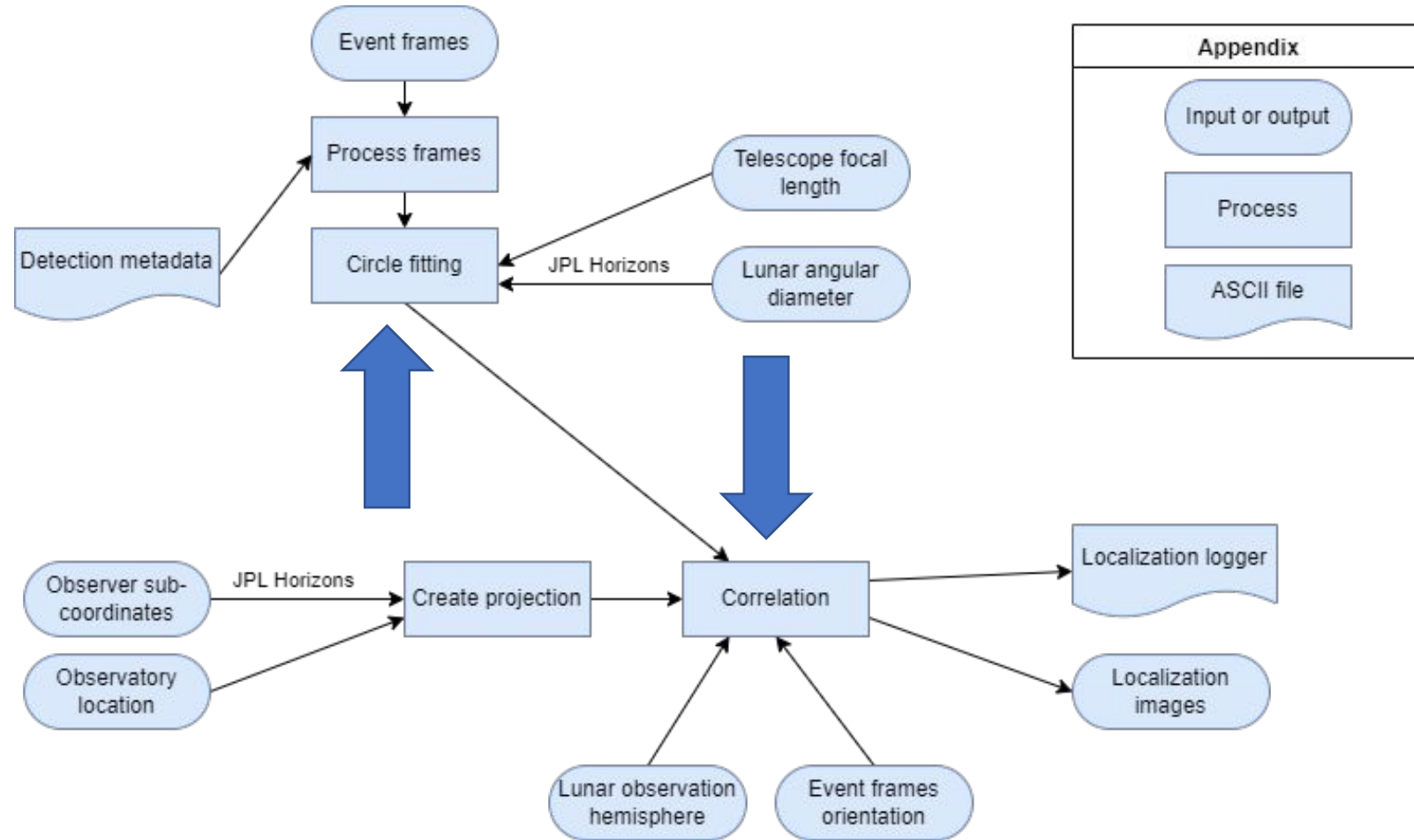
# Localization - Motivation

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- ❖ 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

Center found (pixels):  
X=3068.41, Y=897.90  
Radius found (pixels): 3026.28

Pixel scale (arcsec/pixels): -  
Suggested radius (pixels)  
based on pixel scale: -

Click on the image to get the pixel  
coordinates of the point:

Image (pixels):  
Physical (pixels):

Impact location  
Physical (pixels): X=1930, Y=885

Change focus (zoom) 100%

Visual inspection of the results  
– change color if you want

Change circle color  
#ff2800

The following circle was found:

View circle Hide circle View limb View impact frame

Undo Redo Past attempts  
Reset to initial circle

AUTOMATIC CIRCLE FITTING  
Change the parameters below and click Retry.

Change sd of gaussian filter:  
- 5 + Info

Boost top and bottom % of image:  
- 0% + Info

Retry  
Reset to default

MANUAL CIRCLE FITTING  
Click on the image and then add point  
to manually select limb pixels.  
Click manual fit when ready.

See last 5 points  
Add point Undo previous point  
Clear all points  
Manual fit

Continue

# 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

FDS: Localization

View correlation View moon View rotation

Correlation

Try to match large lunar features

Info Matching pixels: 67.81%

Change match color

#0072b2

Change non-match color

#d55e00

Info Radius (pixels): 2875.53

Go back to circle fitting

Impact flash: green cross mark

Impact flash location (pixels)

Physical: X=1886, Y=3543

Lunar coordinates (deg):

Longitude= -24.54

Latitude= 8.06

Image (pixels):

Physical (pixels):

Create a red cross mark

Mark point Remove mark

Undo Redo

Move history

Reset to initial

50 -25 0 25 50

0 pixels

Shift horizontally

Shift vertically

100%

Change focus (zoom)

Flip vertically and retry

Change rotation angle (based on unrotated image):

# Localization Results

The image displays a file explorer window and a dialog box. The file explorer shows a directory structure: Documents > NELIOTA > Data > 000events\_example > impact Flash. The files listed are localization\_results, Event\_Metadata.txt, and frame\_000.png through frame\_010.png. An orange arrow points from the localization\_results folder to a second file explorer window. This second window shows the contents of the localization\_results folder: 0-impactframe.png, 1-stacked.png, 2-removedLight.png, 3-sobel.png, 4-limb.png, 5-circle.png, 6-projection.png, 7-rotation.png, 8-correlation.png, and localization\_logger.txt. A dialog box titled 'FDS: Localization' is overlaid on the right, containing a question mark icon and the text: 'Result: LONG=60.96, LAT=26.39' (circled in red), 'Proceed and write results to localization\_logger.txt?'. The dialog has 'Yes' and 'No' buttons.

Documents > NELIOTA > Data > 000events\_example > impact Flash

localization\_results

Event\_Metadata.txt

frame\_000.png

frame\_001.png

frame\_002.png

frame\_003.png

frame\_004.png

frame\_005.png

frame\_006.png

frame\_007.png

frame\_008.png

frame\_009.png

frame\_010.png

Data > 000events\_example > impact Flash > localization\_results

0-impactframe.png

1-stacked.png

2-removedLight.png

3-sobel.png

4-limb.png

5-circle.png

6-projection.png

7-rotation.png

8-correlation.png

localization\_logger.txt

FDS: Localization

Result: LONG=60.96, LAT=26.39

Proceed and write results to localization\_logger.txt?

Yes No

**Thanks for your attention**

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