

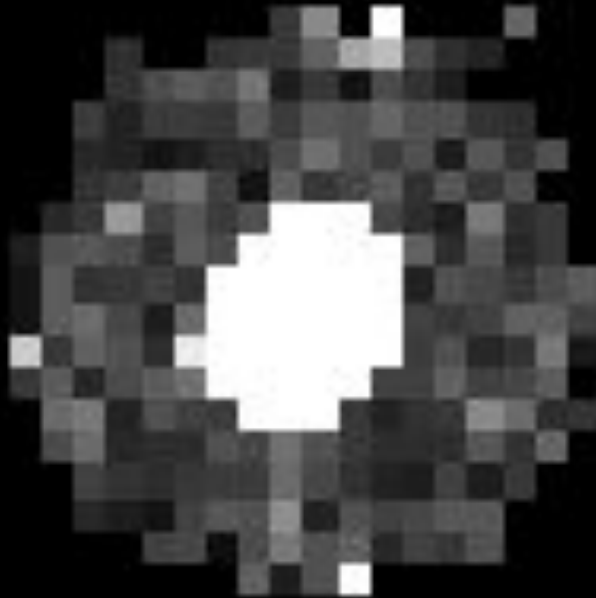
Snowballs detection in Euclid's NISP detectors

IRIS conference: InfraRed Detectors in Space

Calibration and Performance Workshop

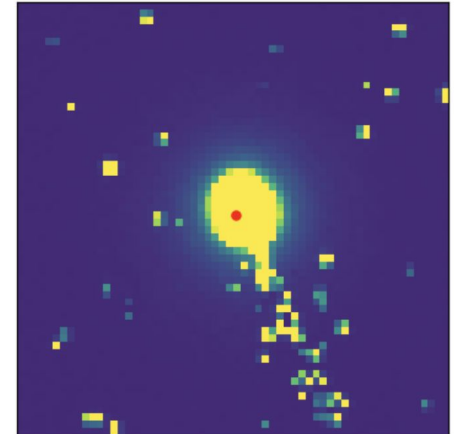
INAF- OAS Bologna

10-12 March



Plan of the presentation

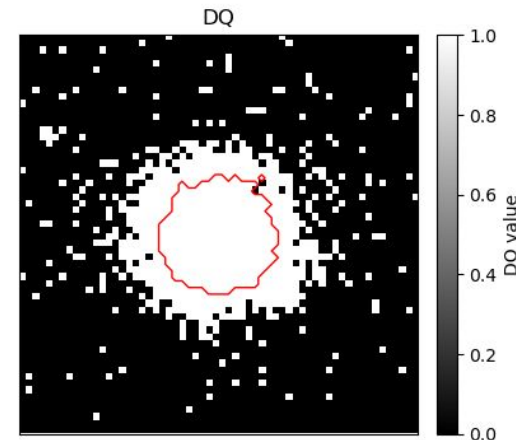
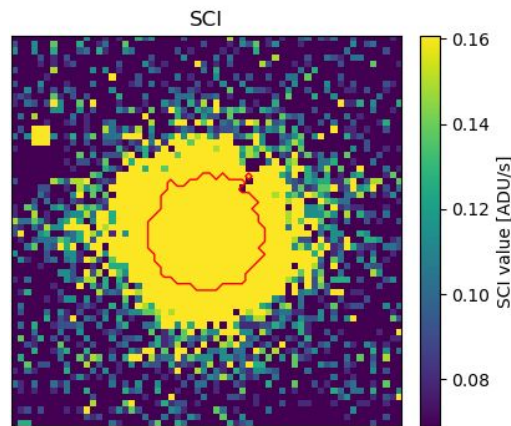
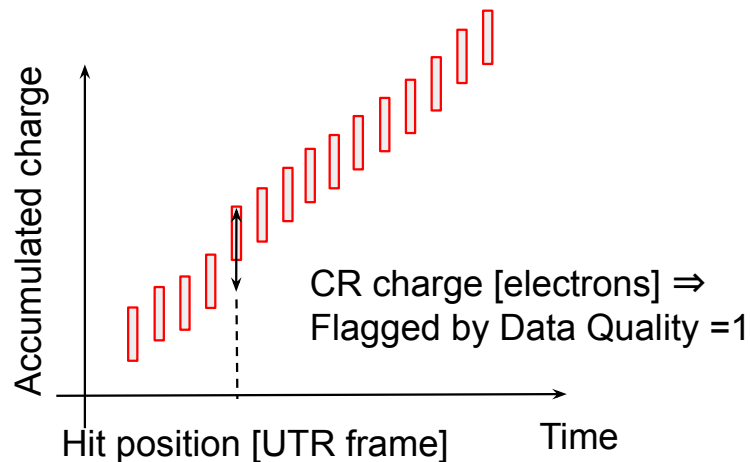
1. **Methodology to detect noise events** occurring during acquisition
2. Quick overview of events collected **on ground and in space**
3. Definition and Identification of **Snowballs / Splashes / Tracks**
4. Conclusion



MACC acquisition mode and Data Quality

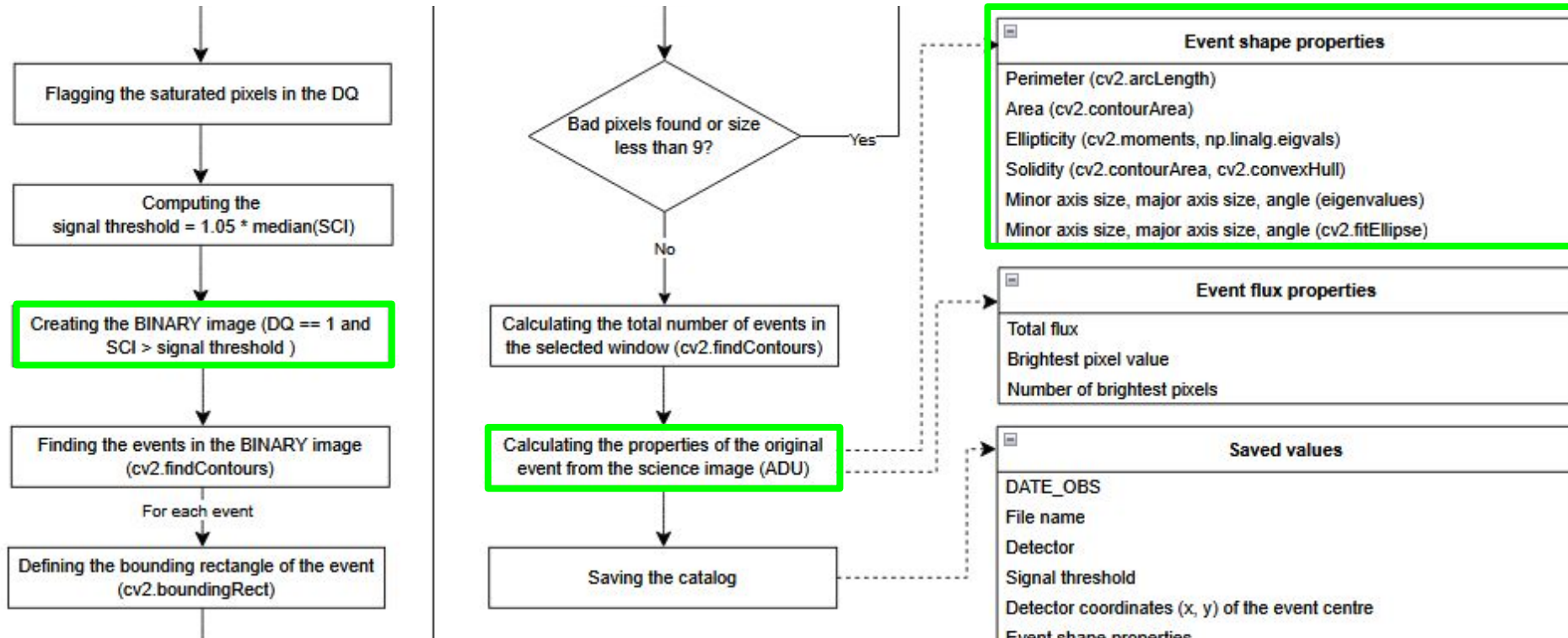
We track noise events occurring during acquisition on the DQ images

Note: Pixels selected with $DQ == 1$ $\rightarrow$ non-linear integration, i.e., total flux reported in the following is a **lower limit** of the deposited charge.



Cosmic Rays And Snowballs Identifier (CRASI)

Events are found in the DQ maps and characterise in the SCIENCE image

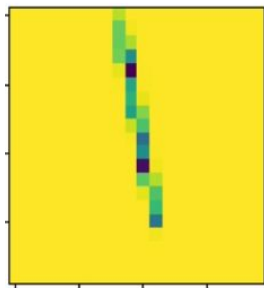
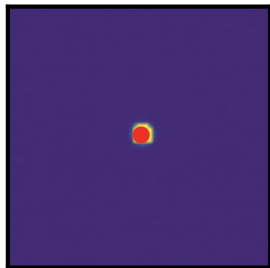


Examples of events on the Ground and in Space

Currently we only look at darks, but soon on scientific images

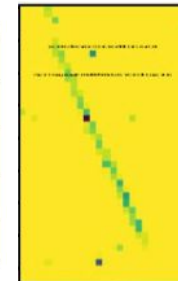
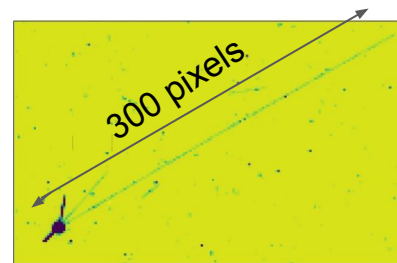
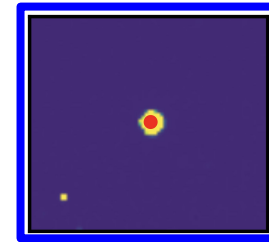
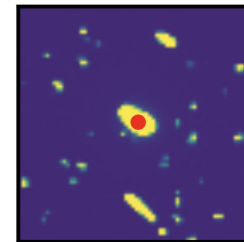
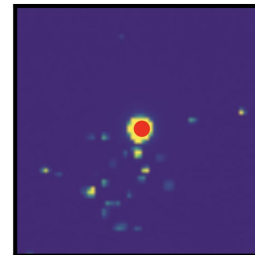
Ground

NISP **Darks** Ground test 2020
3359 NISP images → >8px-Events: 34 094



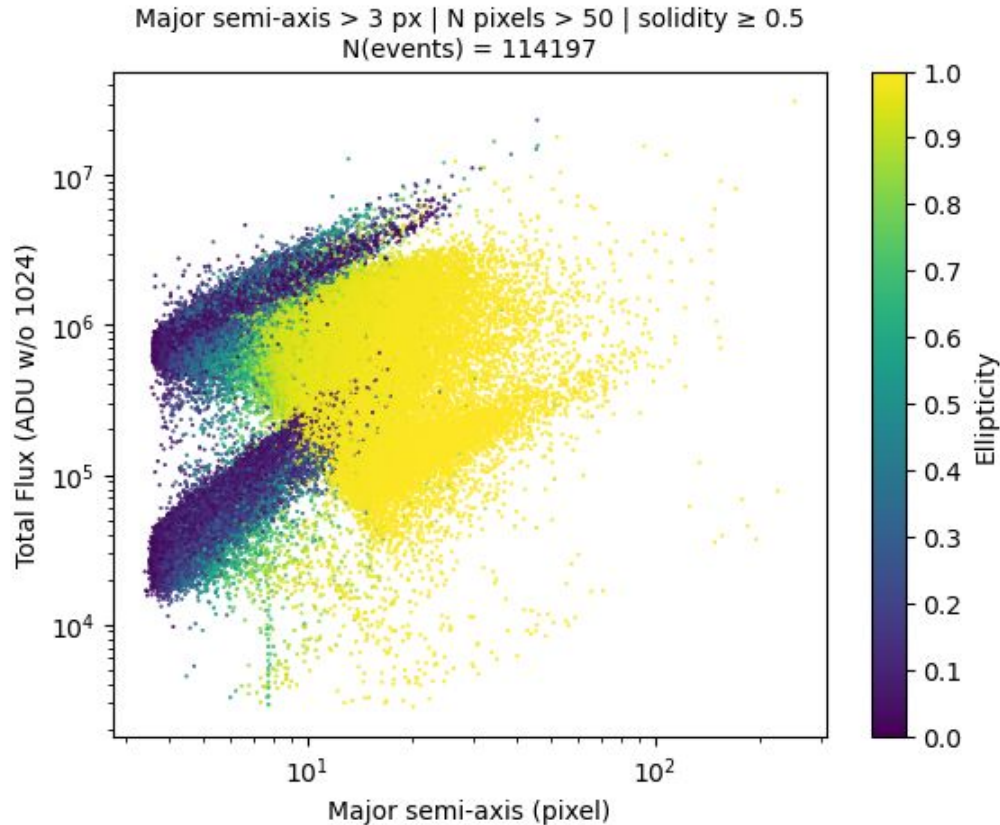
Space

NISP **Slew Darks**: February → July 2024
2342x16 NISP images → >8px-Events: 5 160 662



And many more

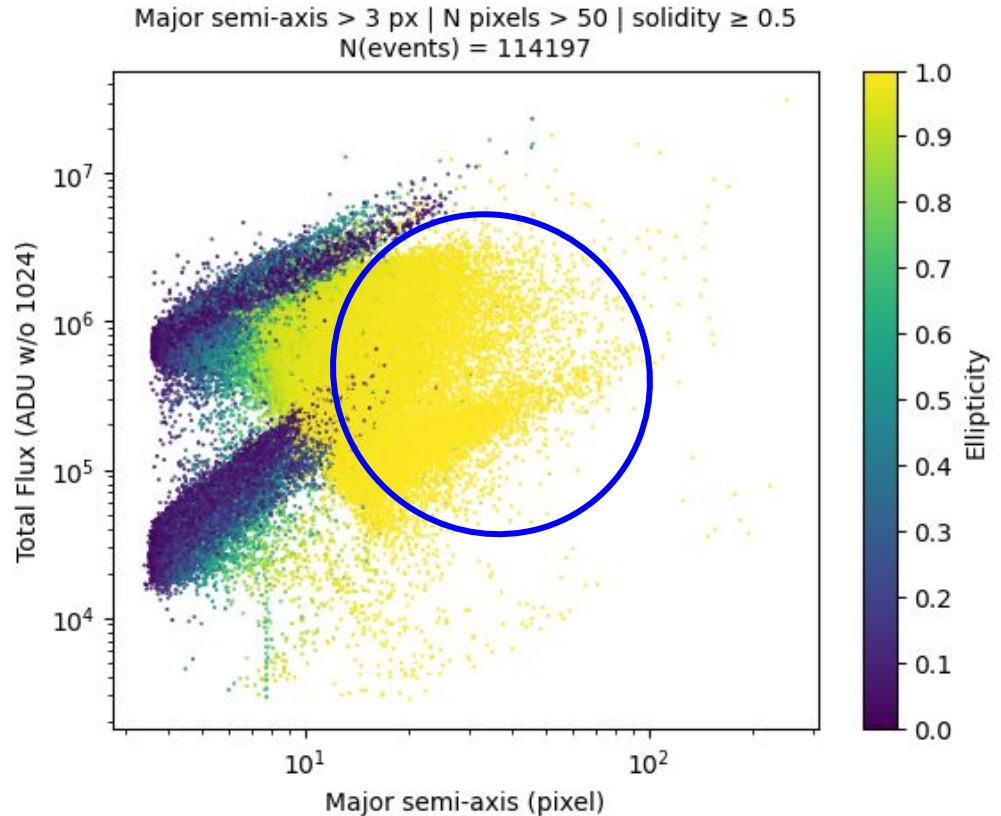
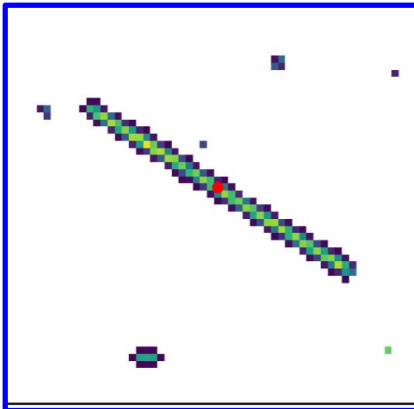
Total Signal [ADU] vs Major semi-axis: Overview of all events detected that contains more than 8 pixels



Total Signal [ADU] vs Major semi-axis: Tracks

Date (UTC): 2024-05-14T07:16:41.987389Z
 CRASI#19421
 DET42: Central px = (498, 1291)
 Window: Bkg = 1076.0 ADU | Counts = 7 events
 Event (139 px): 0 bad px
 Contour: Area = 100 px² | Perimeter = 97 px
 Shape: Ellipticity = 1.0 | Solidity = 0.7
 Flux (ADU): Total = 1333943 | Average px = 9596
 Core (1 px): 56990 ADU

Ellipse:
 Angle (deg): Eigen = 148 | Fit = 148
 Major semi-axis (px): Eigen = 25 | Fit = 27
 Minor semi-axis (px): Eigen = 1 | Fit = 1



Total Signal [ADU] vs Major semi-axis: Snowballs and splashes

Date (UTC): 2024-05-16T00:12:38.244088Z

CRASI#19452

DET31: Central px = (1554, 150)

Window: Bkg = 1074.0 ADU | Counts = 6 events

Event (104 px): 0 bad px

Contour: Area = 86 px² | Perimeter = 40 px

Shape: Ellipticity = 0.0 | Solidity = 0.9

Flux (ADU): Total = 1258852 | Average px = 12104

Core (14 px): 65535 ADU

Ellipse:

Angle (deg): Eigen = 27 | Fit = 130

Major semi-axis (px): Eigen = 5 | Fit = 5

Minor semi-axis (px): Eigen = 5 | Fit = 5



Date (UTC): 2024-05-16T02:39:41.259138Z

CRASI#19472

DET14: Central px = (1883, 1572)

Window: Bkg = 1080.0 ADU | Counts = 10 events

Event (562 px): 0 bad px

Contour: Area = 518 px² | Perimeter = 107 px

Shape: Ellipticity = 0.0 | Solidity = 0.9

Flux (ADU): Total = 3264043 | Average px = 5807

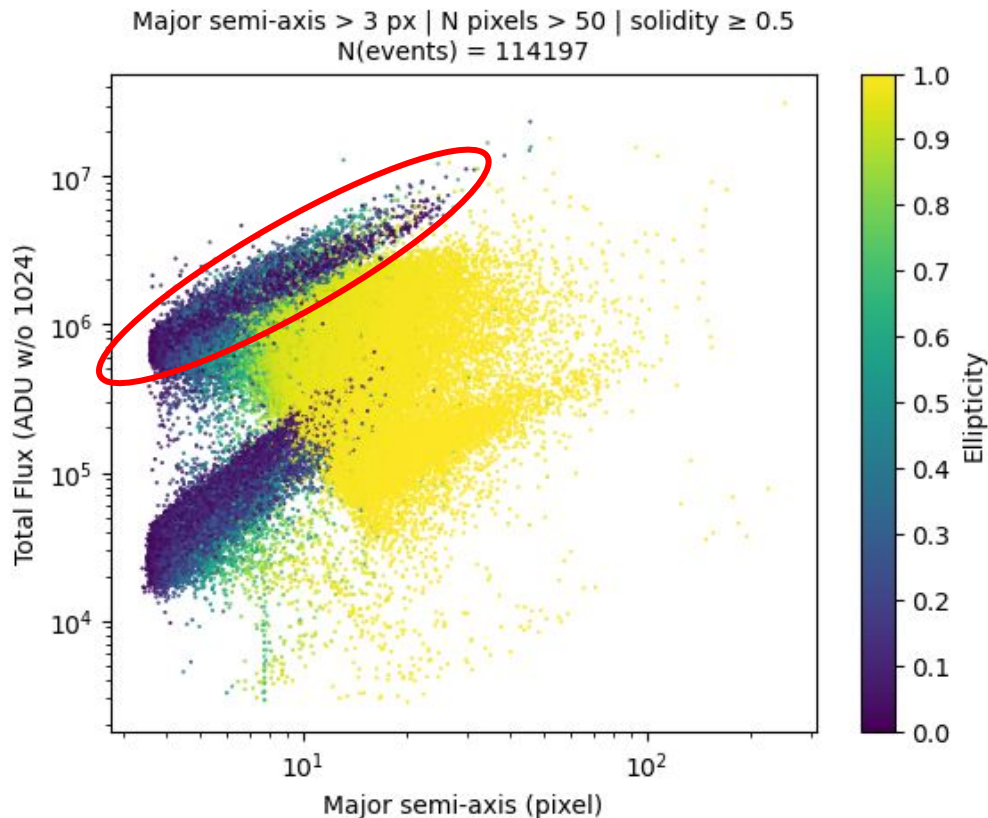
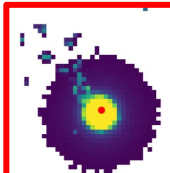
Core (39 px): 65535 ADU

Ellipse:

Angle (deg): Eigen = 121 | Fit = 100

Major semi-axis (px): Eigen = 13 | Fit = 13

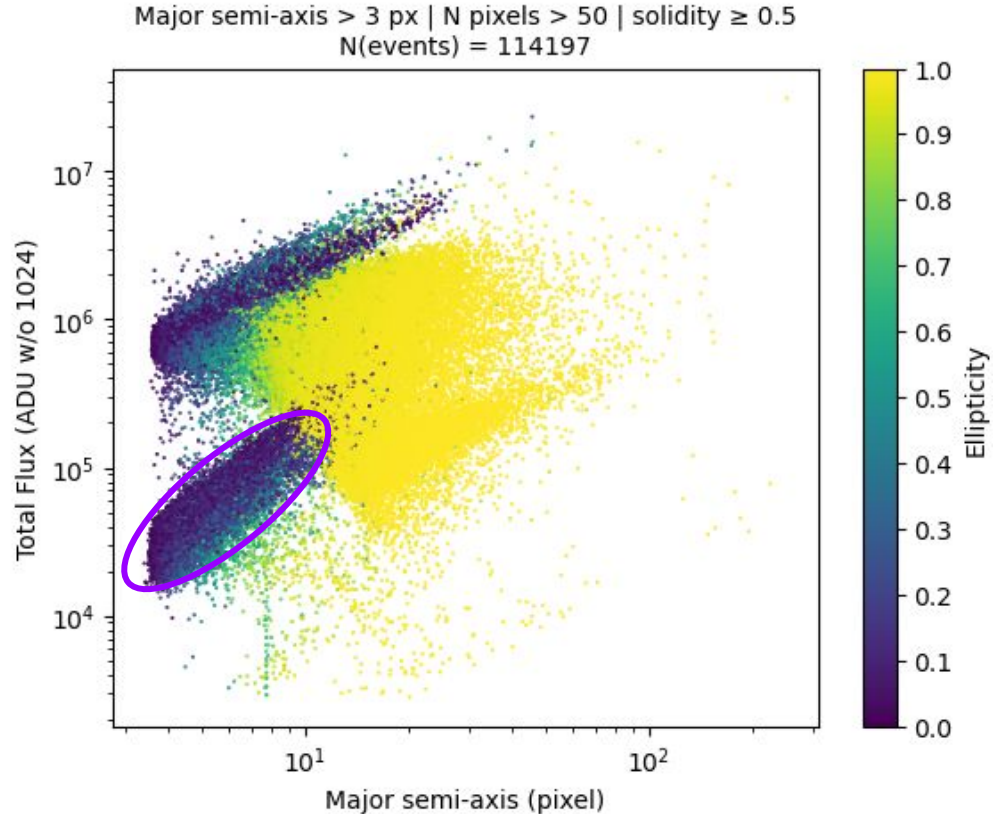
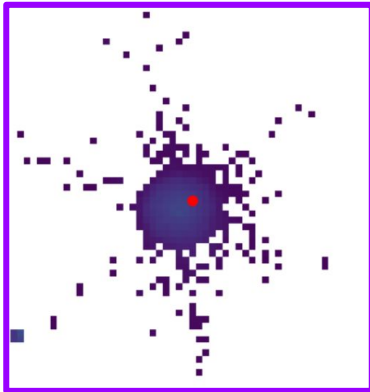
Minor semi-axis (px): Eigen = 13 | Fit = 13



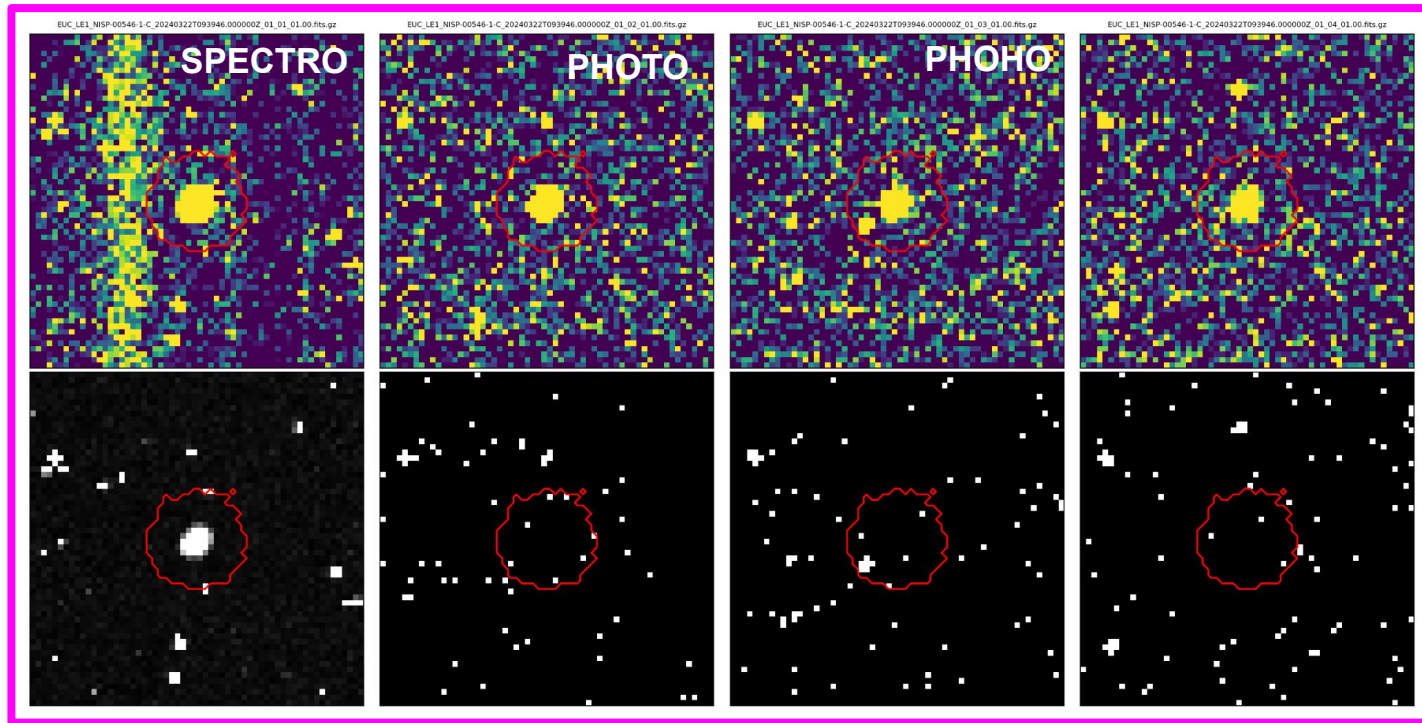
Total Signal [ADU] vs Major semi-axis: Persistence from stars (and from large bright circular noise events)

Date (UTC): 2024-05-16T00:12:38.244088Z
CRASI#19446
DET13: Central px = (1920, 550)
Window: Bkg = 1079.0 ADU | Counts = 52 events
Event (239 px): 0 bad px
Contour: Area = 173 px² | Perimeter = 161 px
Shape: Ellipticity = 0.1 | Solidity = 0.5
Flux (ADU): Total = 109733 | Average px = 459
Core (1 px): 2474 ADU

Ellipse:
Angle (deg): Eigen = 89 | Fit = 107
Major semi-axis (px): Eigen = 8 | Fit = 11
Minor semi-axis (px): Eigen = 7 | Fit = 9



Snowball persistence (over one dither): What happens on the scientific images?



Euclid preliminary

SLEW DARK#1
Events spotted here

SPECTRO
PHOTO
PHOTO
PHOTO

DITHER#1

DITHER#2

DITHER#3

DITHER#4

SLEW DARK#2

0min

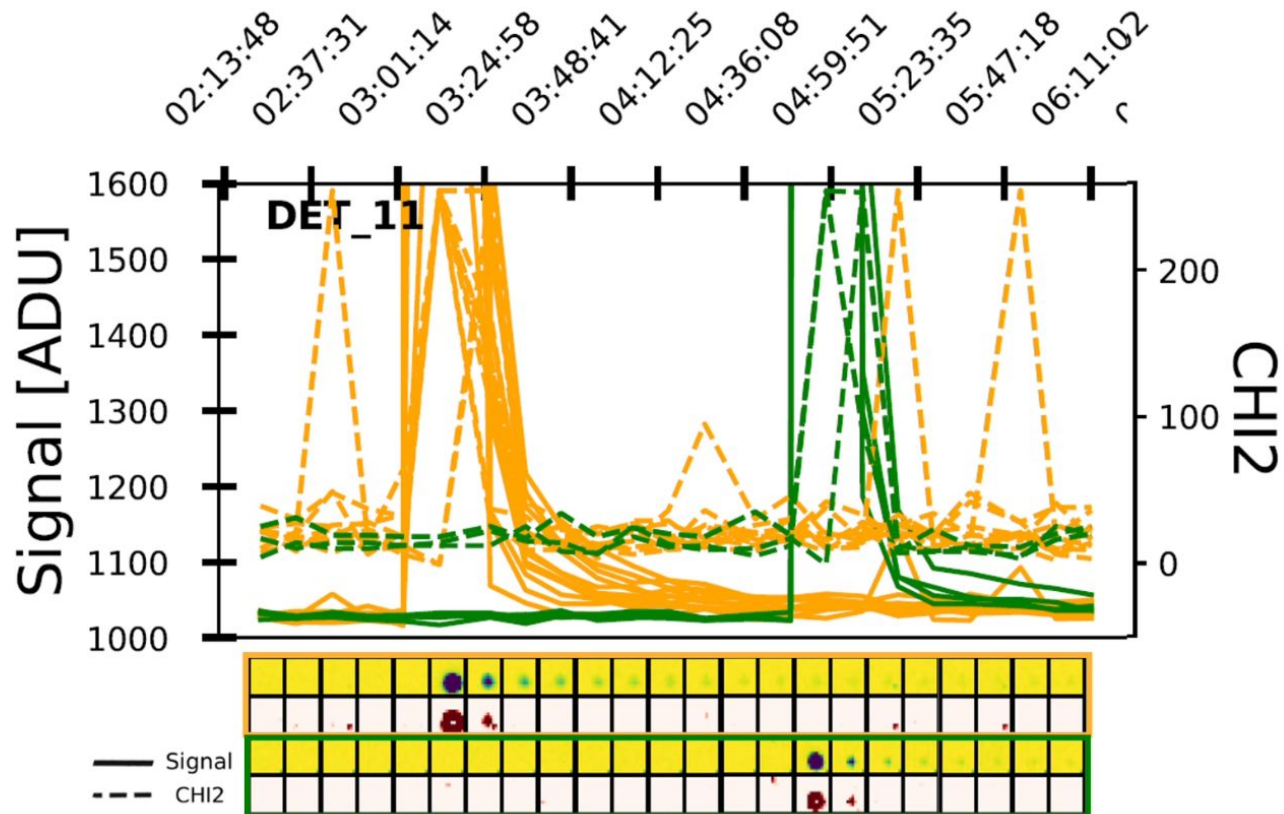
20 min

Snowball persistence (over one dither): What happens on the scientific images?

Persistence from snowballs looks like a very nice emission line in spectroscopy!

⇒ bias on redshift

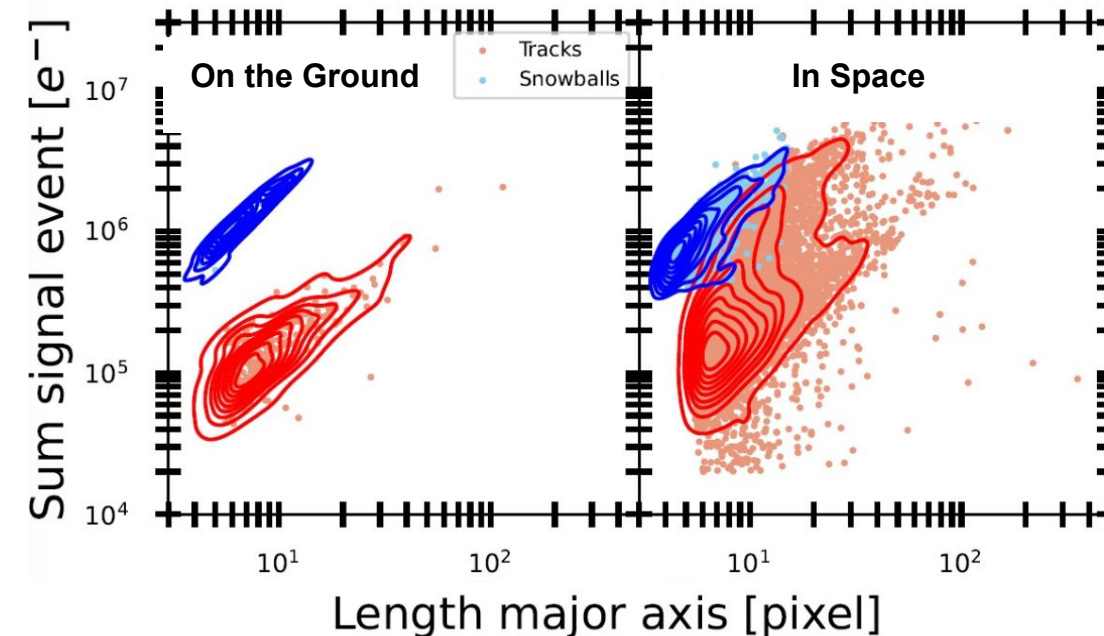
⇒ Bias on Dark Energy



Gabarra PhD thesis (2023)

Analysis made on ground data

Total Signal [ADU] vs Major semi-axis: Snowballs and splashes



Criteria snowballs (& splashes):

- 3 px < Major axis < 8 px
- Ellipticity < 0.2
- Solidity > 0.7
- Saturated core

Criteria tracks:

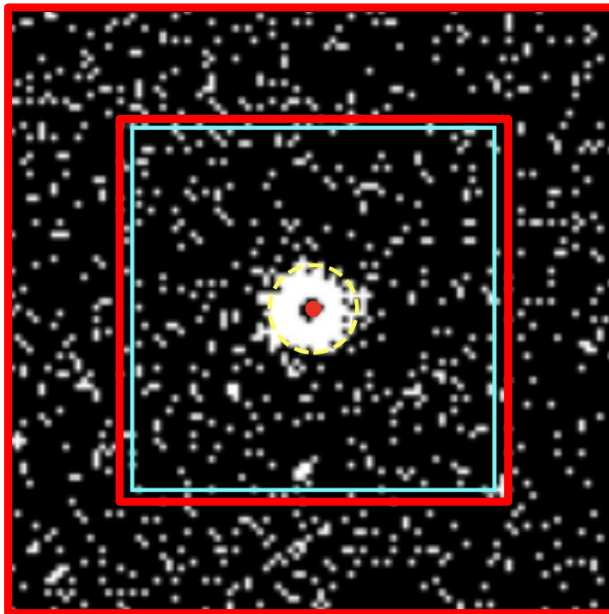
- Major axis > 4 px
- Ellipticity > 0.8
- Solidity > 0.5

Note: We don't differentiate Snowballs from Splashes yet ...

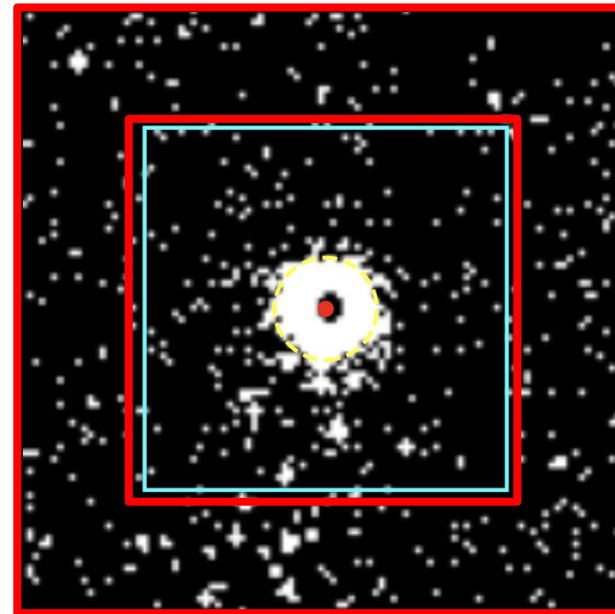
Separating Snowball from Splashes using DQ maps

$$\text{Significance} = (N_{\text{center}}(\text{DQ}==1) - \text{Exp_center}) / \sqrt{(\text{Exp_center} + 1)}$$

R=1.29 Sign=3.16

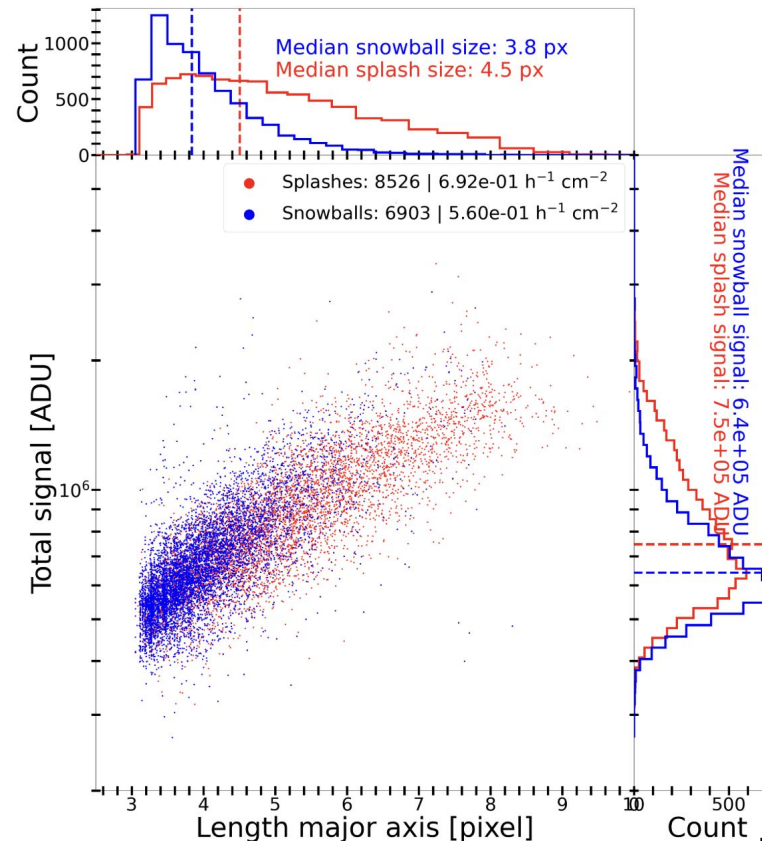


R=2.98 Sign=16.20



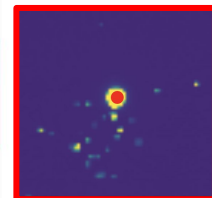
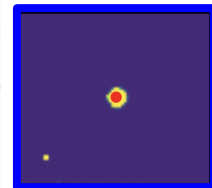
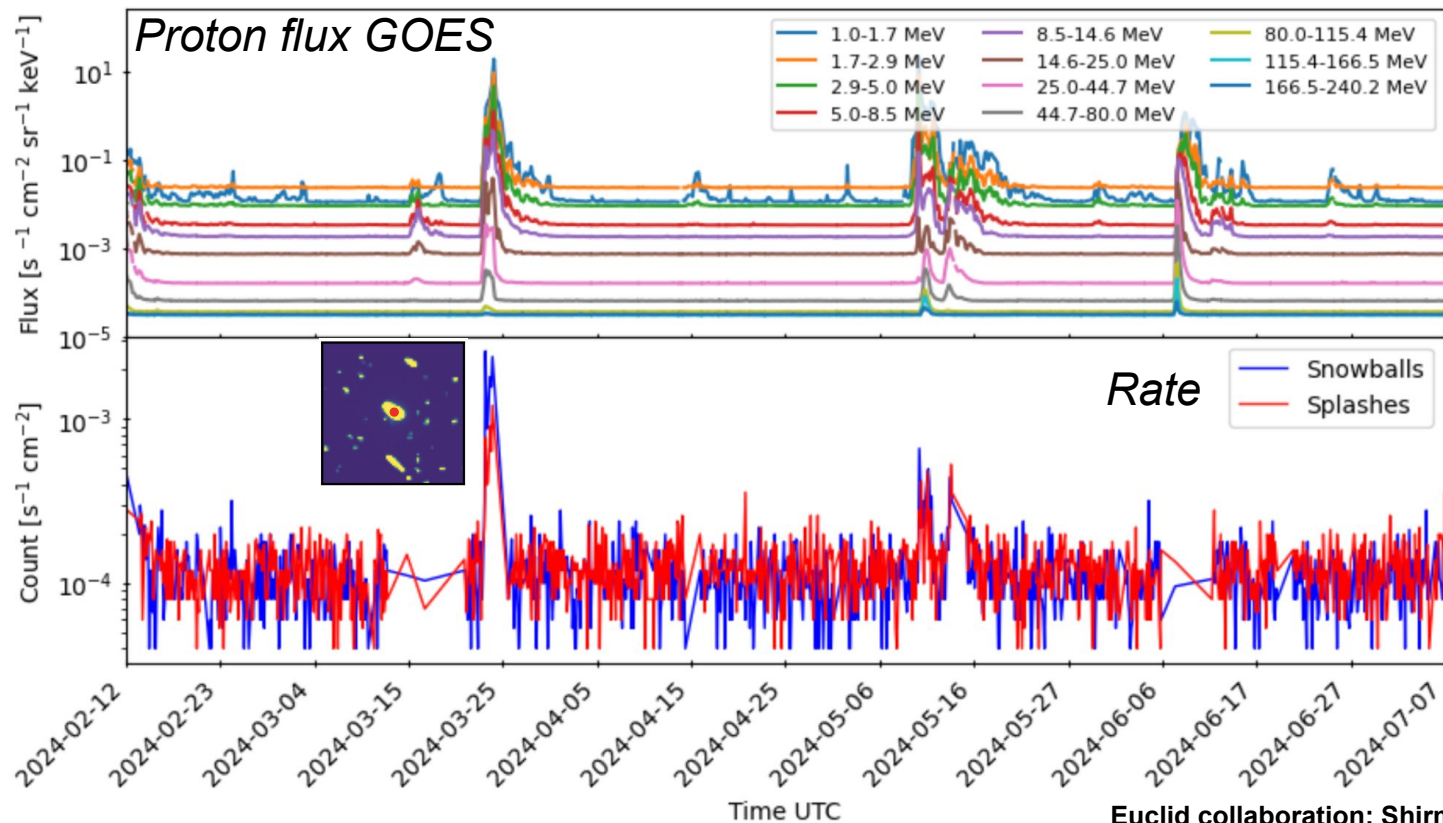
Separating Snowball from Splashes

- Splashes are bigger than Snowballs in average
- Splashes and Snowballs have similar signal distribution on the NISP detector



Euclid NISP Snowballs and Splashes rate versus GOES S1 data

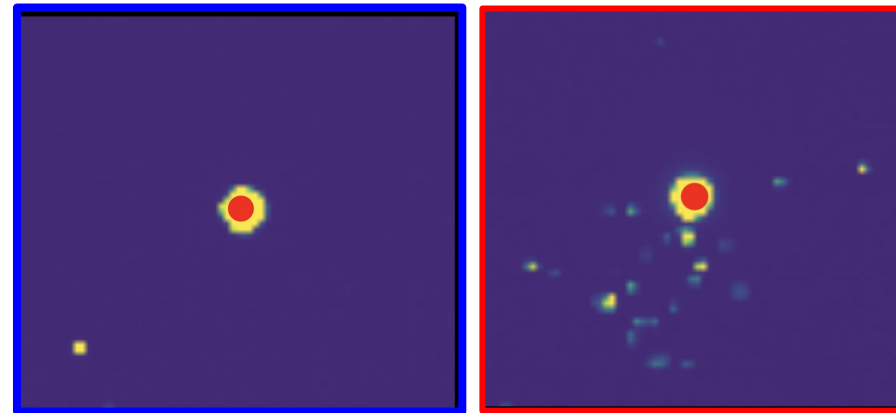
The algorithm to separate Snowballs from Splashes currently fails during solar flares



Summing up the statistics on **Snowballs & Splashes**

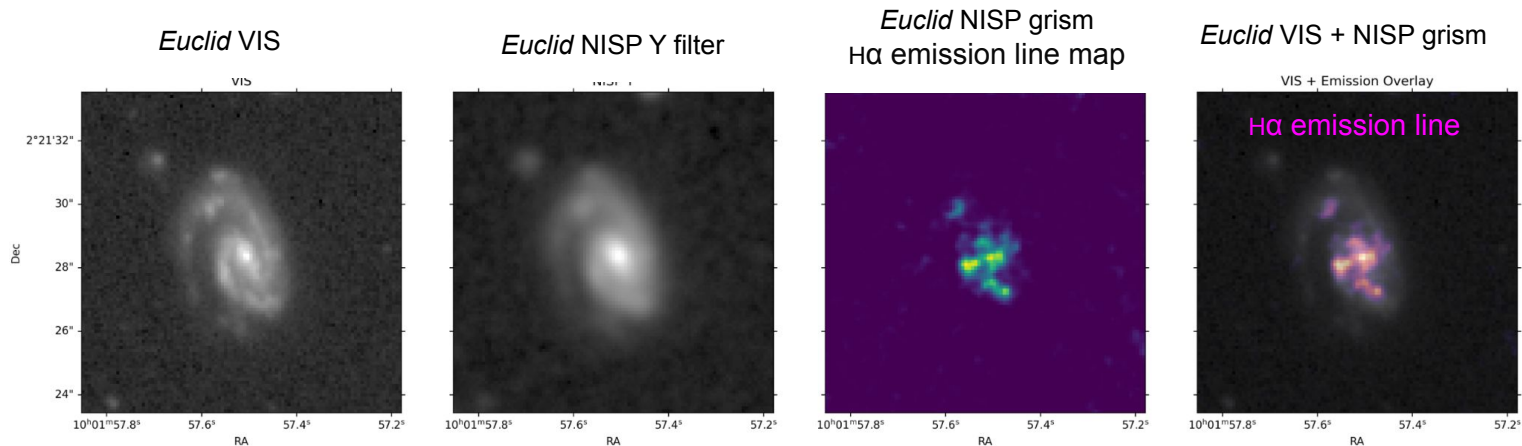
- **Measured snowball rates:**
 - Ground = $0.03 \text{ /cm}^2\text{/hr}$ $\Rightarrow \sim 200\times$ higher in space
 - Space = $5.6 \text{ /cm}^2\text{/hr}$
- **Measured splash rate in space:** $6.9 \text{ /cm}^2\text{/hr}$.

Note: Currently our rate is hardly comparable to **JWST statistics**, a consistent analysis should be performed

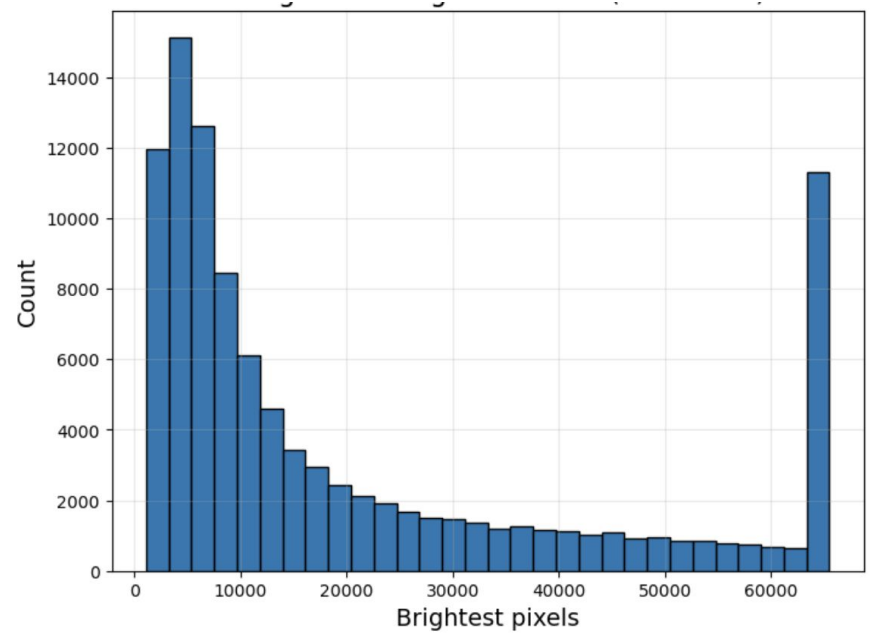
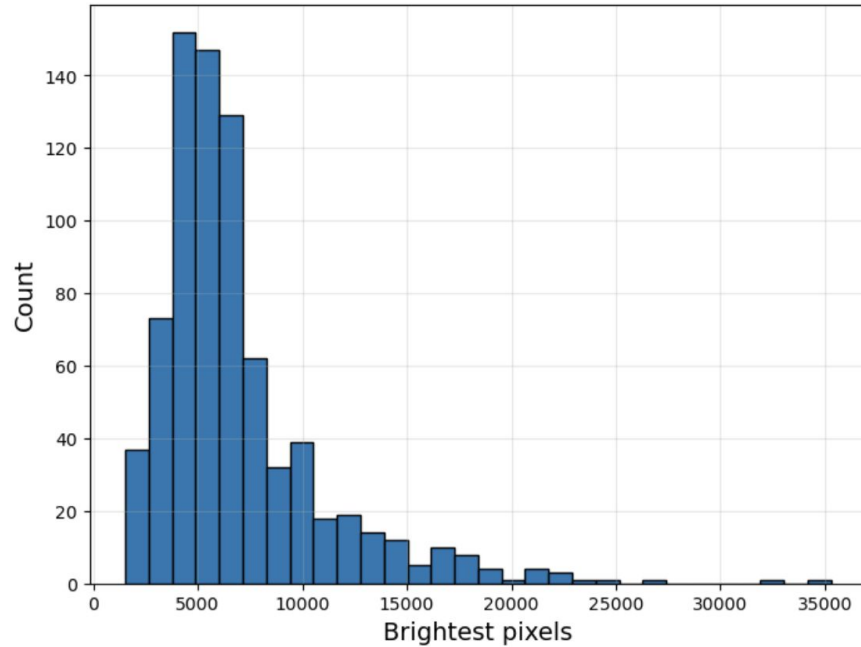


Next steps and Conclusion

- Apply CRASI to SCIENCE images
- Compare to other methods
 - To classification with Gaussian Mixture Model (GMM) clustering (ask Marija about it)
 - To see **astrocrappy analysis** (Go check the poster by Evandro Balbi!)
- Study of **Snowballs & Splashes persistence** & compare to official *Euclid* model (S. Conseil)
- Consolidating **JWST and *Euclid* statistic** for long term monitoring ?



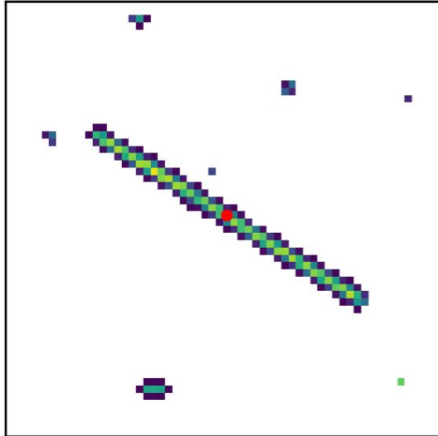
Comparison ground space (Tracks)



Tracks

Date (UTC): 2024-05-14T07:16:41.987389Z
 CRASI#19421
 DET42: Central px = (498, 1291)
 Window: Bkg = 1076.0 ADU | Counts = 7 events
 Event (139 px): 0 bad px
 Contour: Area = 100 px² | Perimeter = 97 px
 Shape: Ellipticity = 1.0 | Solidity = 0.7
 Flux (ADU): Total = 1333943 | Average px = 9596
 Core (1 px): 56990 ADU

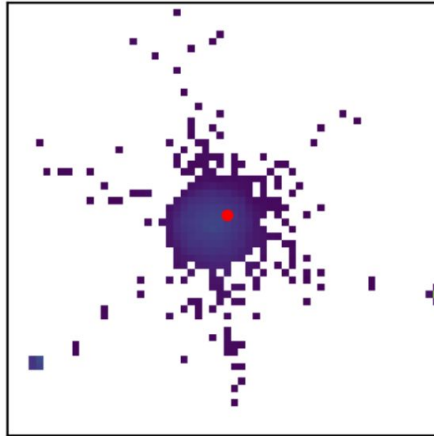
Ellipse:
 Angle (deg): Eigen = 148 | Fit = 148
 Major semi-axis (px): Eigen = 25 | Fit = 27
 Minor semi-axis (px): Eigen = 1 | Fit = 1



Star Persistence

Date (UTC): 2024-05-16T00:12:38.244088Z
 CRASI#19446
 DET13: Central px = (1920, 550)
 Window: Bkg = 1079.0 ADU | Counts = 52 events
 Event (239 px): 0 bad px
 Contour: Area = 173 px² | Perimeter = 161 px
 Shape: Ellipticity = 0.1 | Solidity = 0.5
 Flux (ADU): Total = 109733 | Average px = 459
 Core (1 px): 2474 ADU

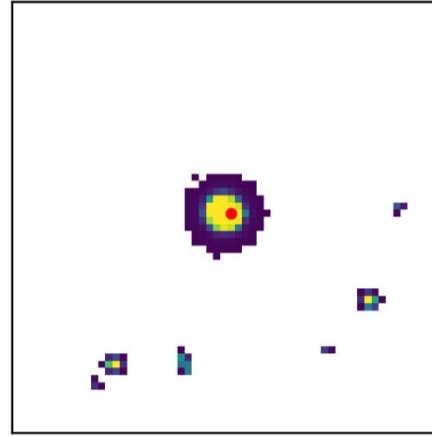
Ellipse:
 Angle (deg): Eigen = 89 | Fit = 107
 Major semi-axis (px): Eigen = 8 | Fit = 11
 Minor semi-axis (px): Eigen = 7 | Fit = 9



Snowball

Date (UTC): 2024-05-16T00:12:38.244088Z
 CRASI#19452
 DET31: Central px = (1554, 150)
 Window: Bkg = 1074.0 ADU | Counts = 6 events
 Event (104 px): 0 bad px
 Contour: Area = 86 px² | Perimeter = 40 px
 Shape: Ellipticity = 0.0 | Solidity = 0.9
 Flux (ADU): Total = 1258852 | Average px = 12104
 Core (14 px): 65535 ADU

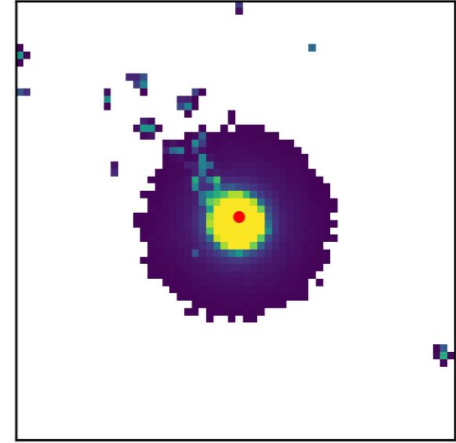
Ellipse:
 Angle (deg): Eigen = 27 | Fit = 130
 Major semi-axis (px): Eigen = 5 | Fit = 5
 Minor semi-axis (px): Eigen = 5 | Fit = 5



Noisy Snowball

Date (UTC): 2024-05-16T02:39:41.259138Z
 CRASI#19472
 DET14: Central px = (1883, 1572)
 Window: Bkg = 1080.0 ADU | Counts = 10 events
 Event (562 px): 0 bad px
 Contour: Area = 518 px² | Perimeter = 107 px
 Shape: Ellipticity = 0.0 | Solidity = 0.9
 Flux (ADU): Total = 3264043 | Average px = 5807
 Core (39 px): 65535 ADU

Ellipse:
 Angle (deg): Eigen = 121 | Fit = 100
 Major semi-axis (px): Eigen = 13 | Fit = 13
 Minor semi-axis (px): Eigen = 13 | Fit = 13



NISP SLEW DARKS: February → July 2024

Around 2000 NISP images → Events: 5160662

Catalogue available on upon request

Tracks

Star Persistence

Snowball

Noisy Snowball

Date (UTC): 2024-05-14T07:16:41.987389Z
CRASI#19421
DET42: Central px = (498, 1291)
Window: Bkg = 1076.0 ADU | Counts = 7 events
Event (139 px): 0 bad px
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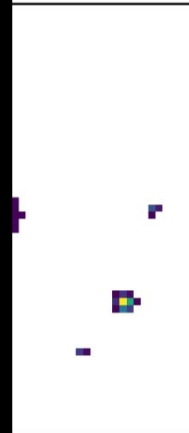
Ellipse:
Angle (deg): Eigen = 148 | Fit = 148
Major semi-axis (px): Eigen = 25 | Fit = 27
Minor semi-axis (px): Eigen = 1 | Fit = 1

2:38.244088Z

CRASI#19472
DET14: Central px = (1883, 1572)
Window: Bkg = 1080.0 ADU | Counts = 10 events
Event (562 px): 0 bad px
Contour: Area = 518 px² | Perimeter = 107 px
Shape: Ellipticity = 0.0 | Solidity = 0.9
Flux (ADU): Total = 3264043 | Average px = 5807
Core (39 px): 65535 ADU

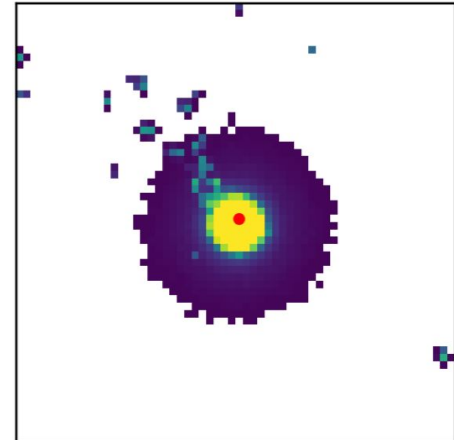
Perimeter = 40 px
Solidity = 0.9
Average px = 12104

Angle (deg): Eigen = 130 | Fit = 5
Major semi-axis (px): Eigen = 5 | Fit = 5
Minor semi-axis (px): Eigen = 5 | Fit = 5



Date (UTC): 2024-05-16T02:39:41.259138Z
CRASI#19472
DET14: Central px = (1883, 1572)
Window: Bkg = 1080.0 ADU | Counts = 10 events
Event (562 px): 0 bad px
Contour: Area = 518 px² | Perimeter = 107 px
Shape: Ellipticity = 0.0 | Solidity = 0.9
Flux (ADU): Total = 3264043 | Average px = 5807
Core (39 px): 65535 ADU

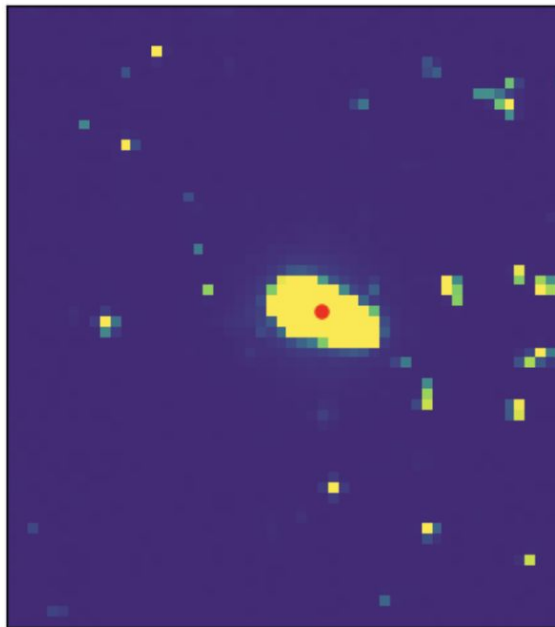
Ellipse:
Angle (deg): Eigen = 121 | Fit = 100
Major semi-axis (px): Eigen = 13 | Fit = 13
Minor semi-axis (px): Eigen = 13 | Fit = 13



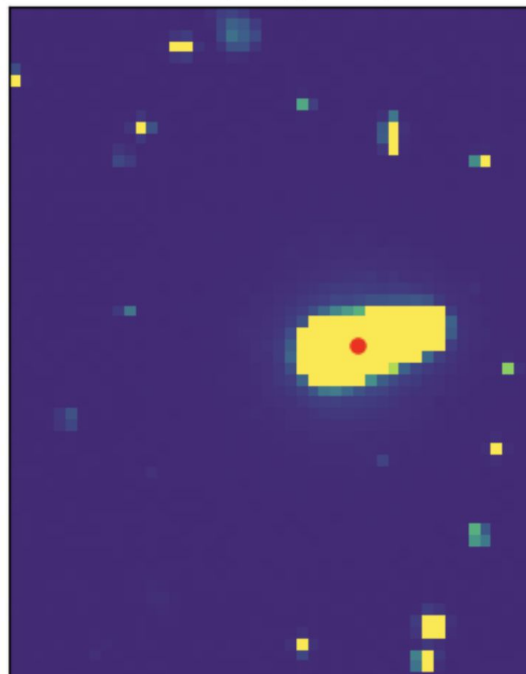
Example of rejected. ONLY SEEN IN SPACE SNOWBALL WITH SIZE >10

Applying shift: $dx=0$, $dy=0$

ell=0.13 maj=8.4 sol=0.89 Splash_minus_median=-6.00 SNR=-1.01 Splash=27

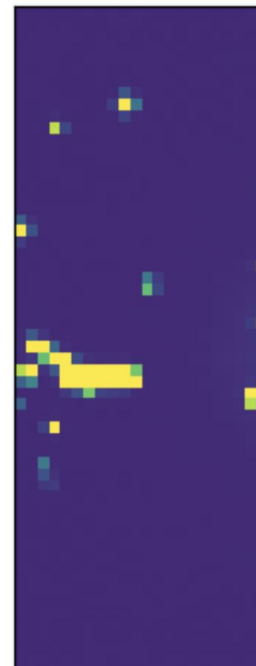


ell=0.14 maj=9.9 sol=0.85 Splash_minus_median=-7.1



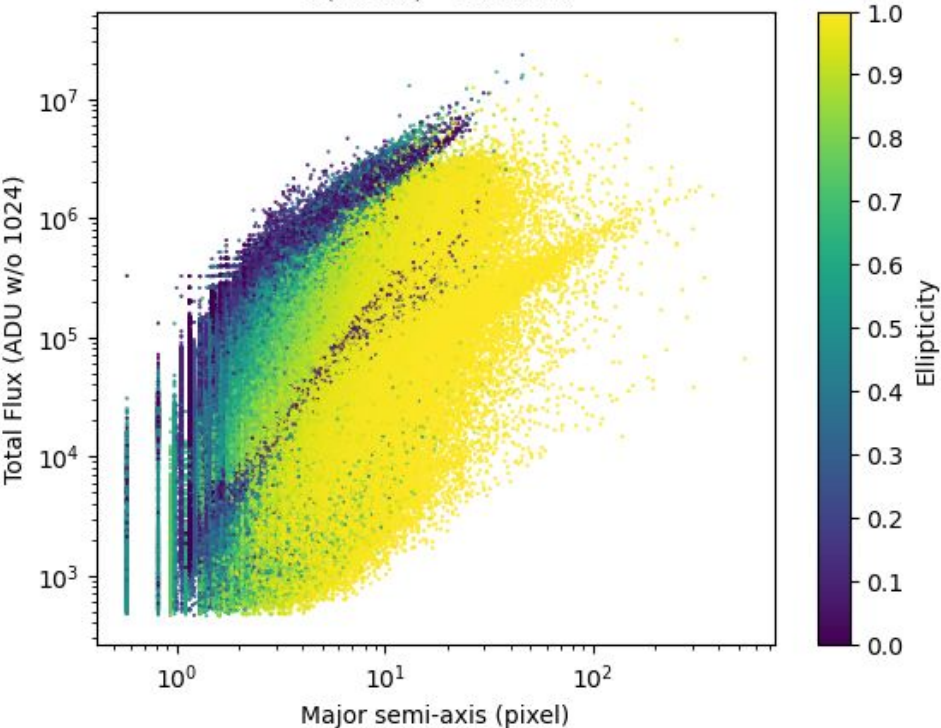
Applying shift: $dx=0$, $dy=0$

ell=0.11 maj=11.6 sol=0.88 Spl



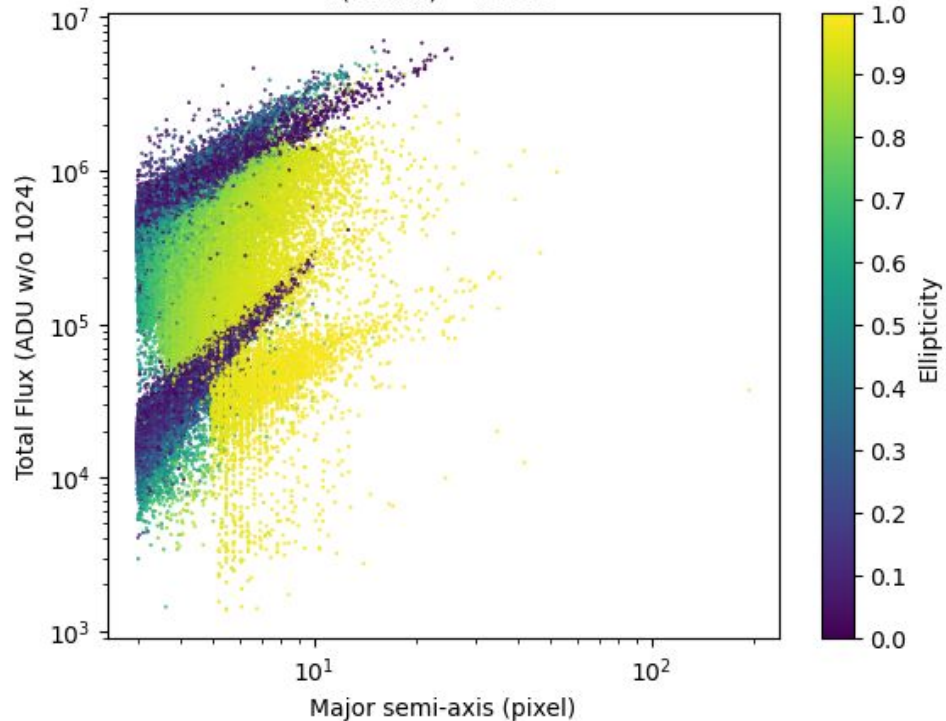
FULL CATALOGUE

Full Catalogue | N pixels > 8
N(events) = 5160662



SUB-CATALOGUE#1

Major semi-axis > 3 px | N pixels > 20 | solidity ≥ 0.9
N(events) = 160867



Biggest snowballs and splashes (outliers). Although very interesting they are removed from the sample. ONLY SEEN IN SPACE