Image subtraction and transient detection with LSST Software

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CONTEXT

- With the LSST, there will be an enormous amount of information to process.

- We can detect even more transient and variable objects in the obtained images.

- The LSST DM has developed several tools that can be used for the astronomical image processing foreseen.

OBJECTIVES

- Evaluate the capacity of Stack for astronomical image processing.

- Understand and work with the different algorithms of image subtraction for transient objects detection.

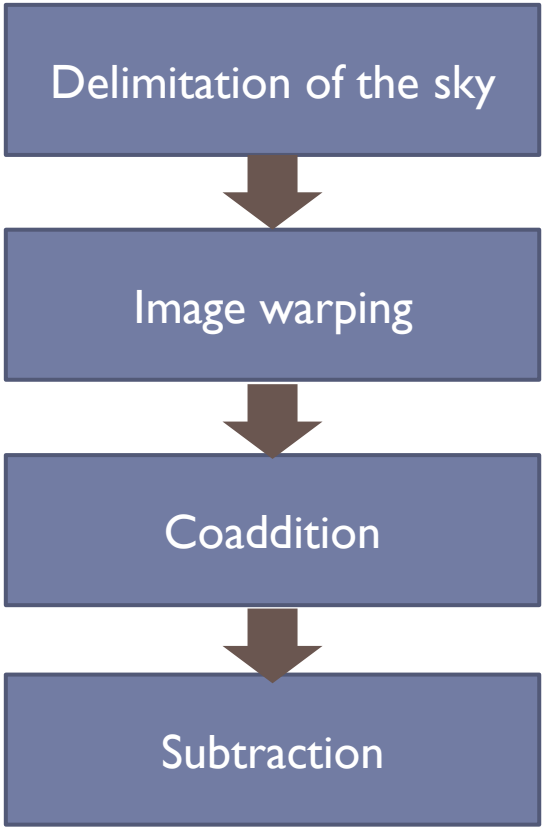
- Propose improvements over the algorithmic and the existing methods within the libraries.

STATE OF THE ART
Stack

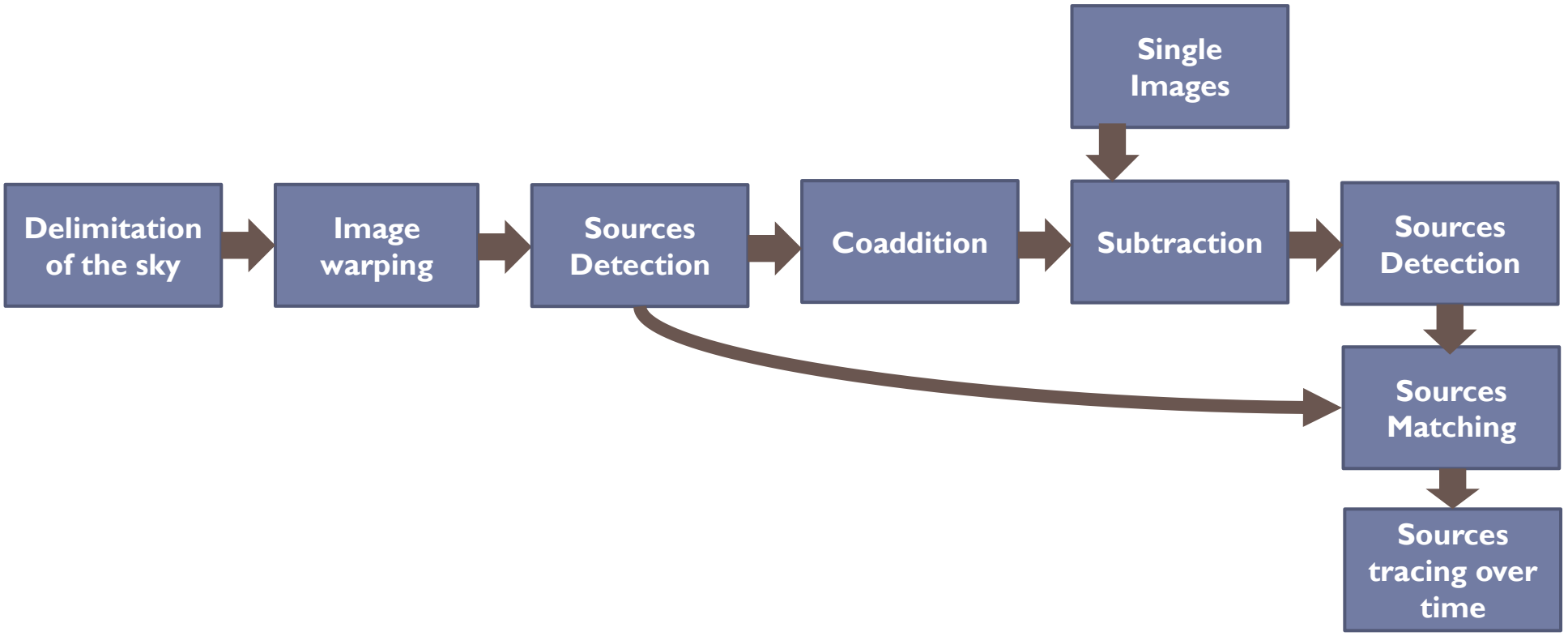
- Coaddition of images.
- Subtraction of exposures.
  - PSF Matching: some methods implemented.
- Detection of sources.

METHODOLOGY
Detection of transients

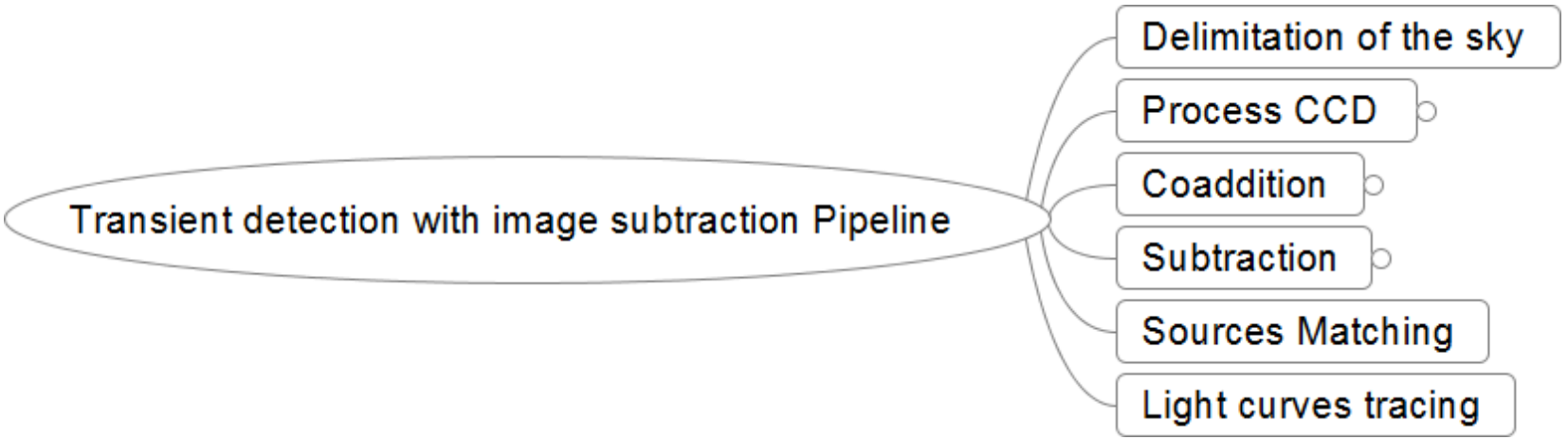
- A reference frame on the sky has to be defined.
- Coaddition allows the generation of deep noiseless images.
- To subtract, images should be PSF-matched.



METHODOLOGY
Detection of transients



WHAT IS IMPLEMENTED?



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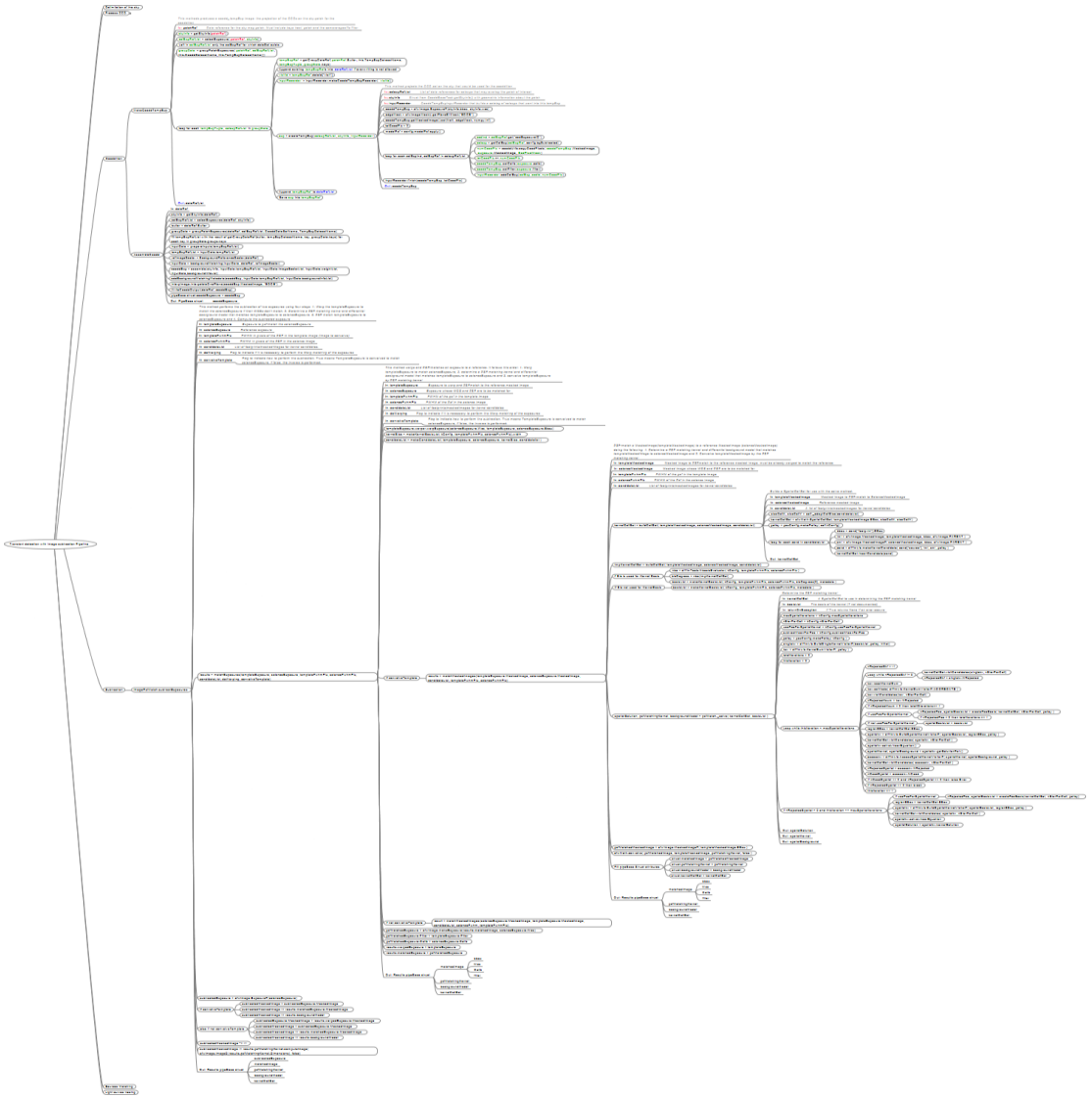

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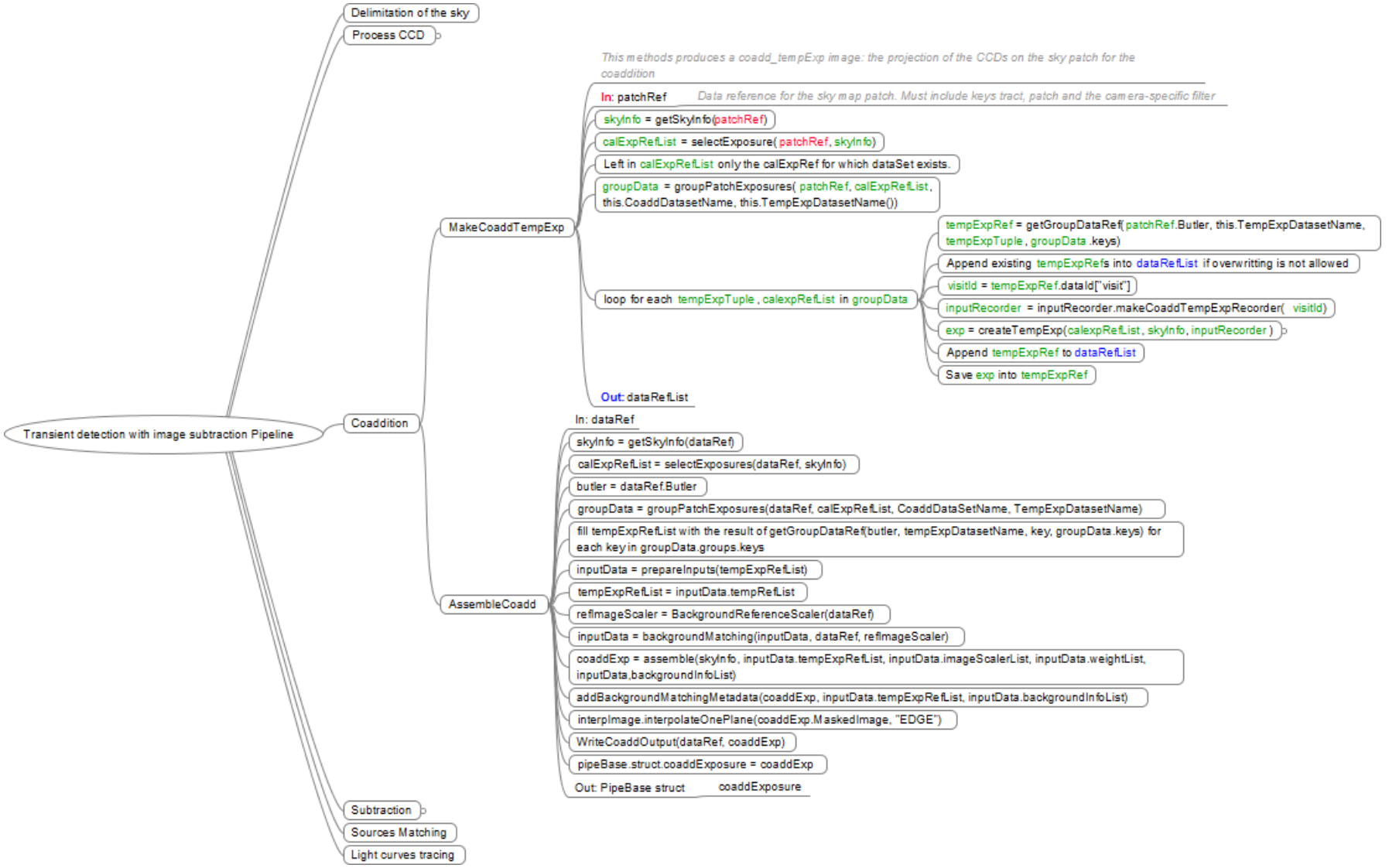

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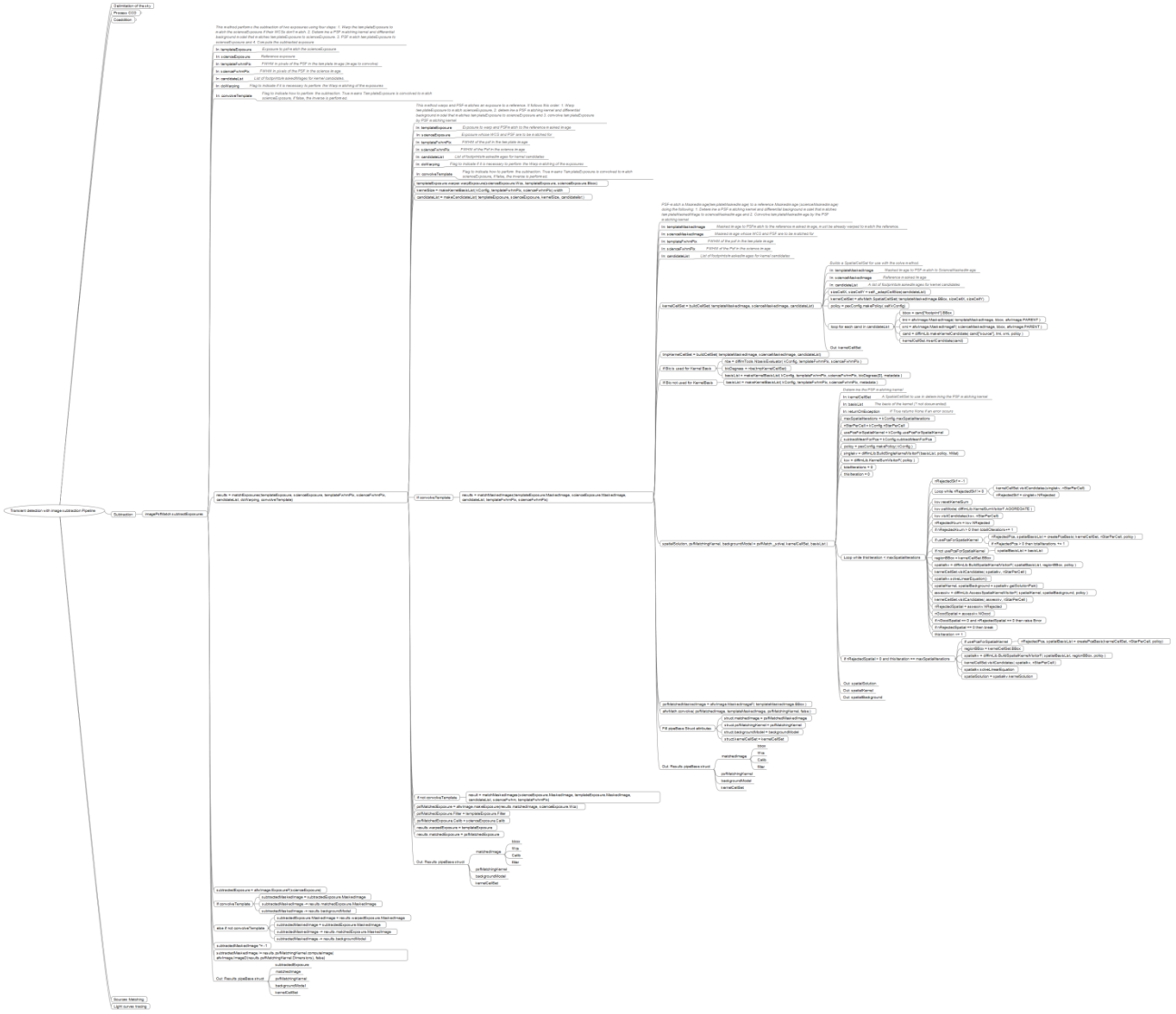


WHAT IS IMPLEMENTED?

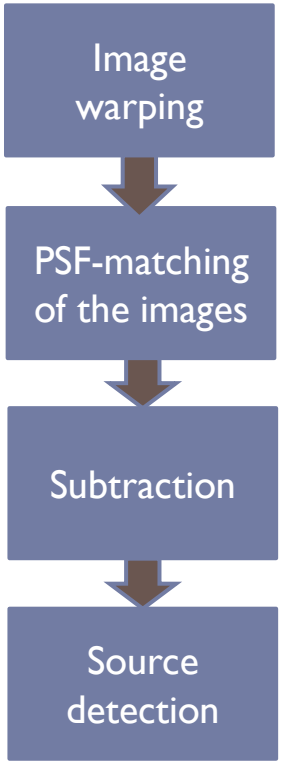
- Documentation for the different tasks and how-to-use guide are being generated.
- Tasks with the Stack format are being tested to keep new developments within the standard.
- We are handling the different pieces of code that allows us to assemble a transient-detection pipe line.

SUBTRACTION
How is it done?

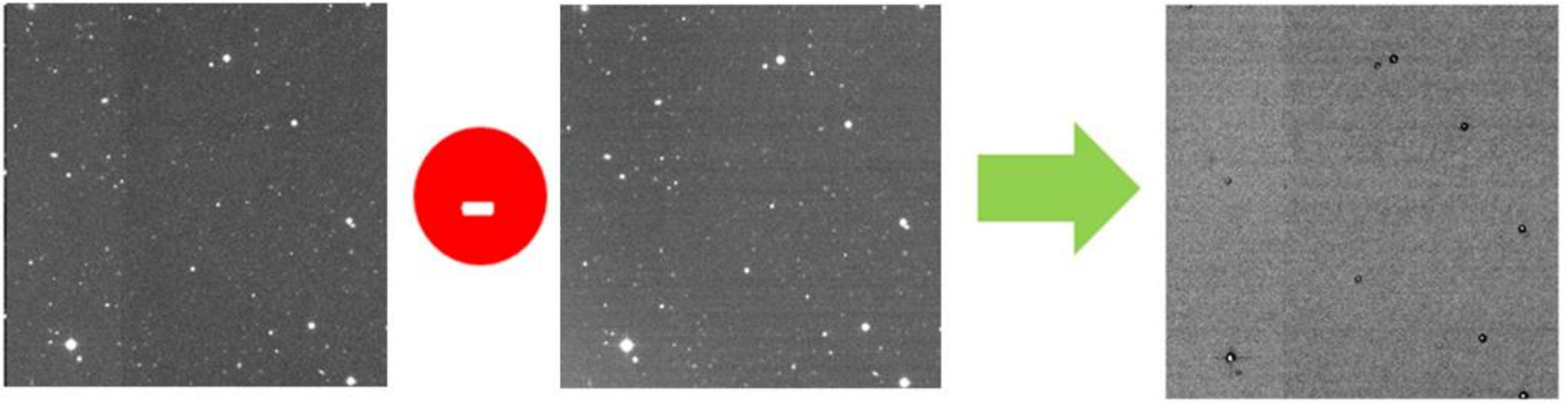
- Images should be aligned to the sky map.
- The two exposures have to be PSF-matched, so it is necessary to calculate a convolution (preferably) kernel, and degrade the best one.
- After PSF-matching the images, the exposures are subtracted. Remaining objects are the ones which have changed their brightness or position.

SUBTRACTION
How is it done?

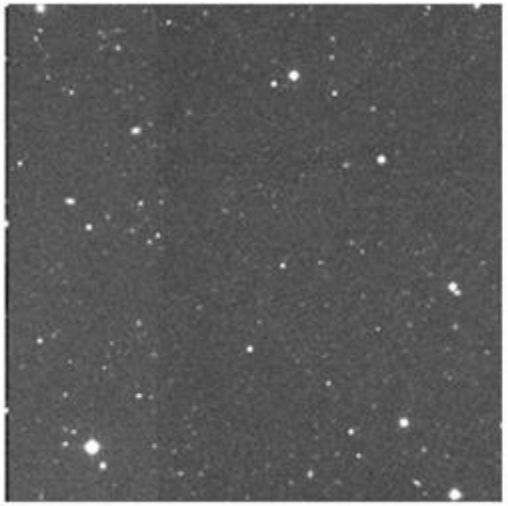
- The PSF-matching should adjust the image with better seeing and low noise to the other one.
- Basis set and Spatial Model has to be carefully picked. Solutions for the kernel may not be unique.



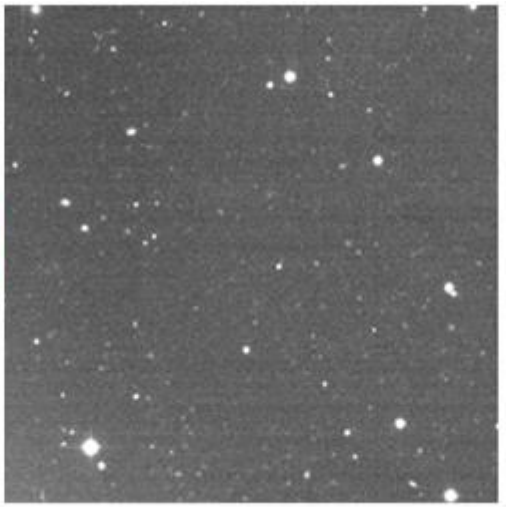
SUBTRACTION
How is it done?



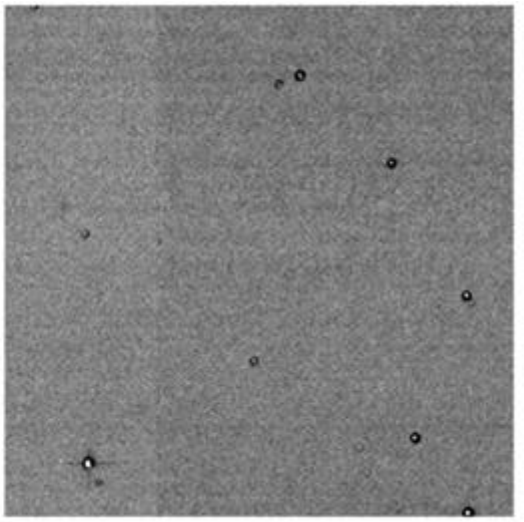
SUBTRACTION
How is it done?



Template Exposure (T)



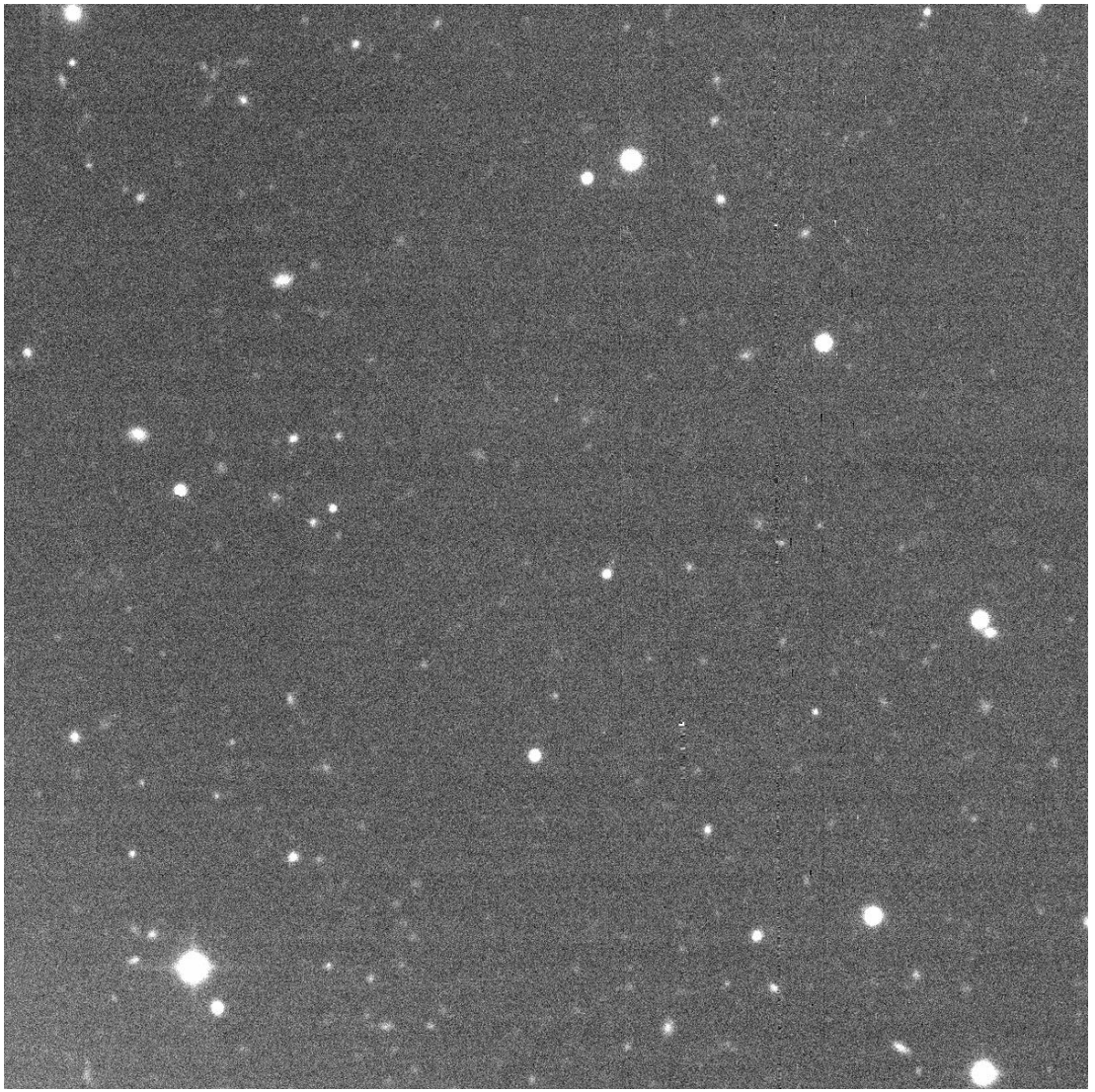
Science Exposure (I)



Difference Exposure (D)

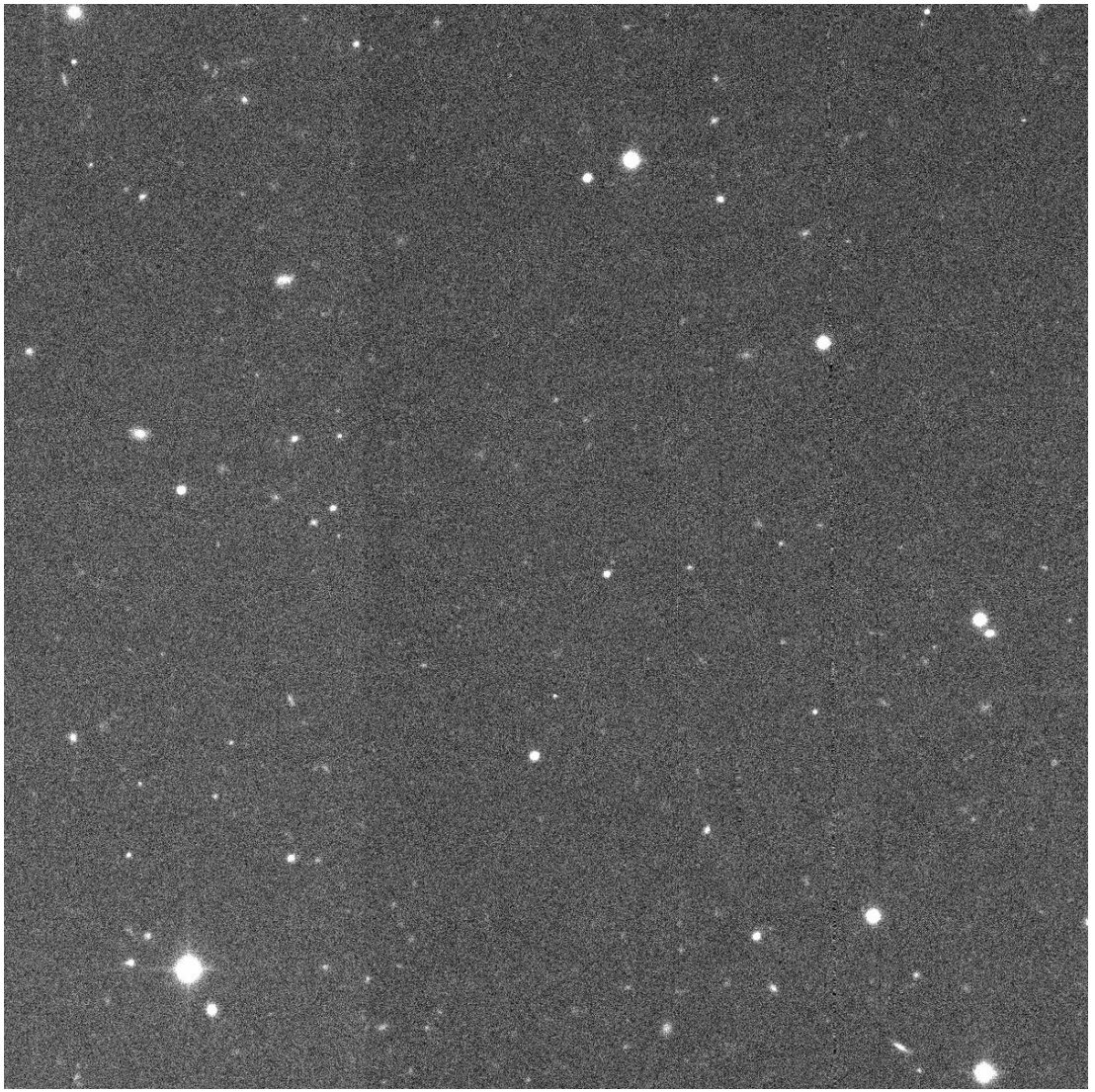
$$D = I - (K \otimes T)$$

TESTS
Set of images with a known supernova



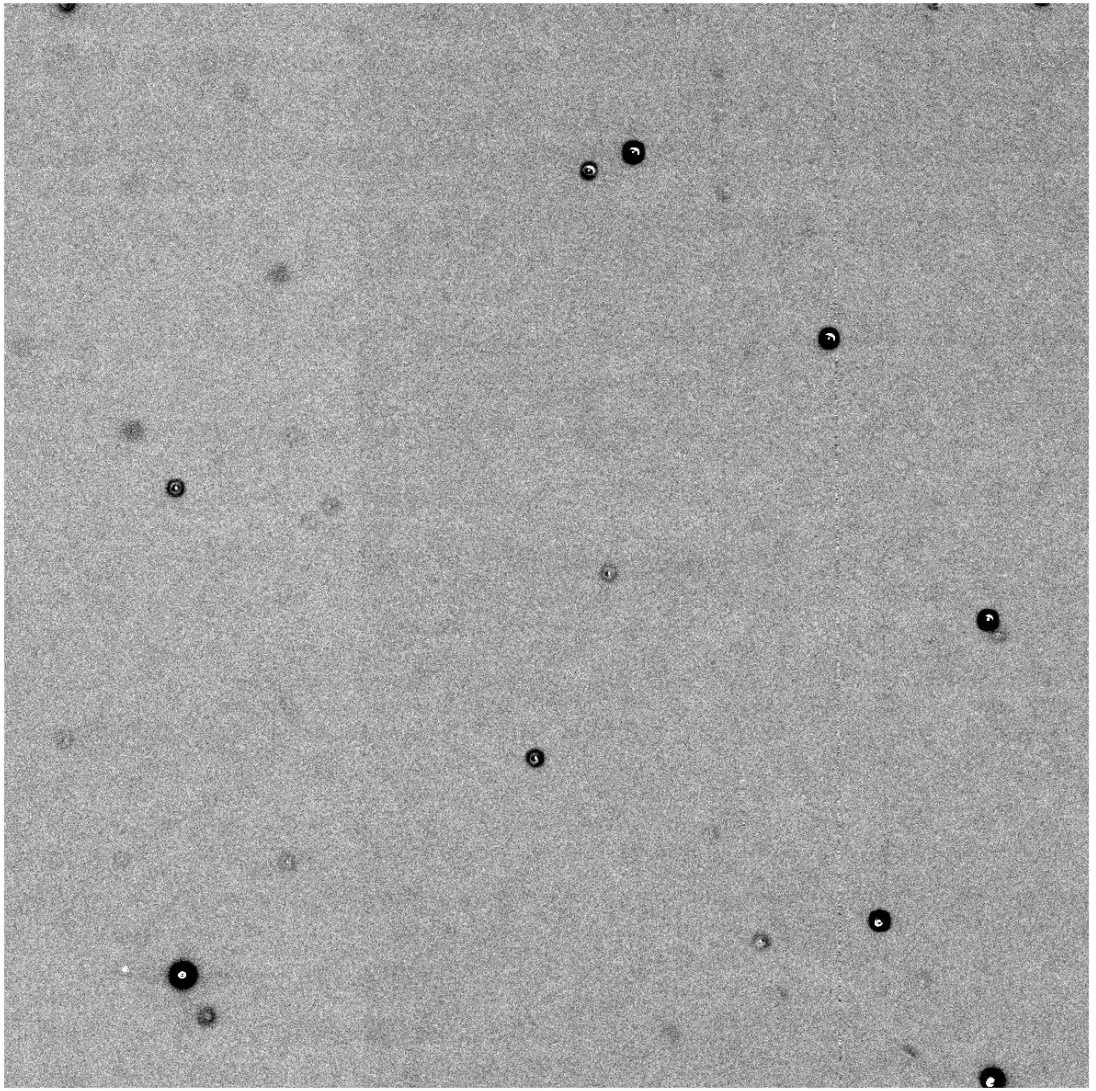
Coaddition of different time

TESTS
Set of images with a known supernova



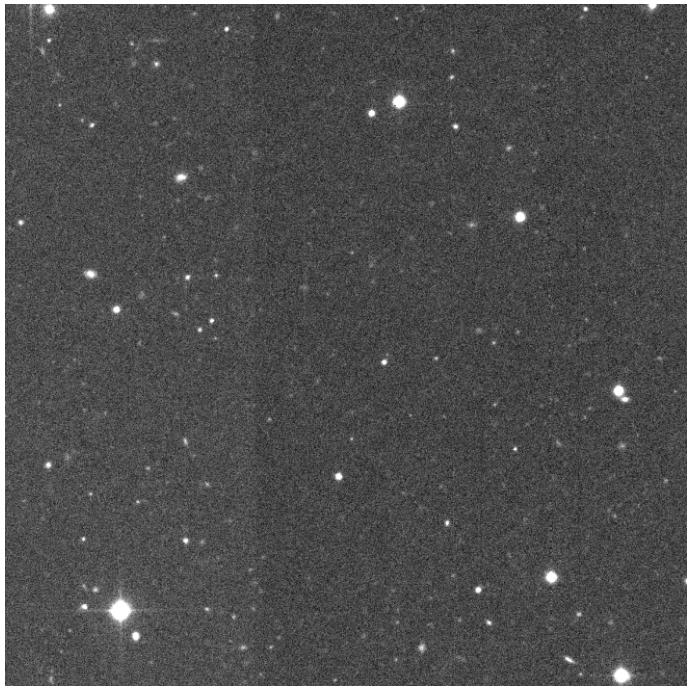
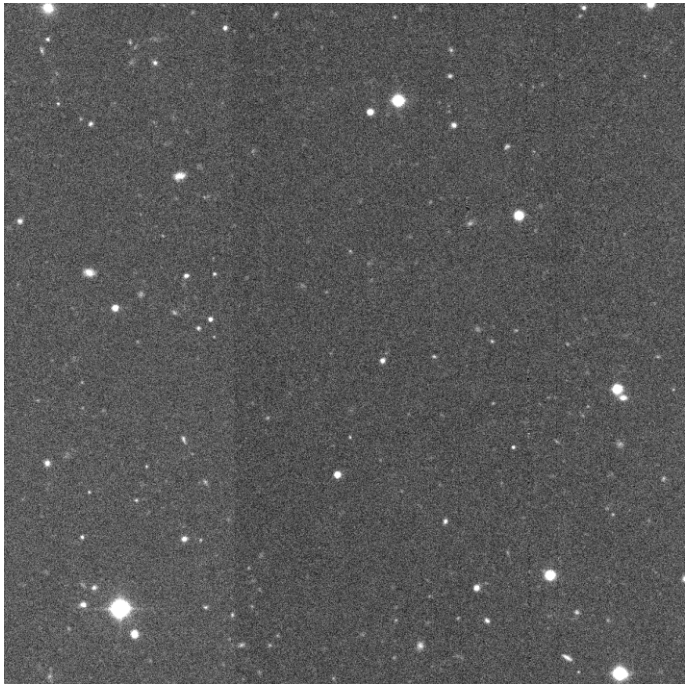
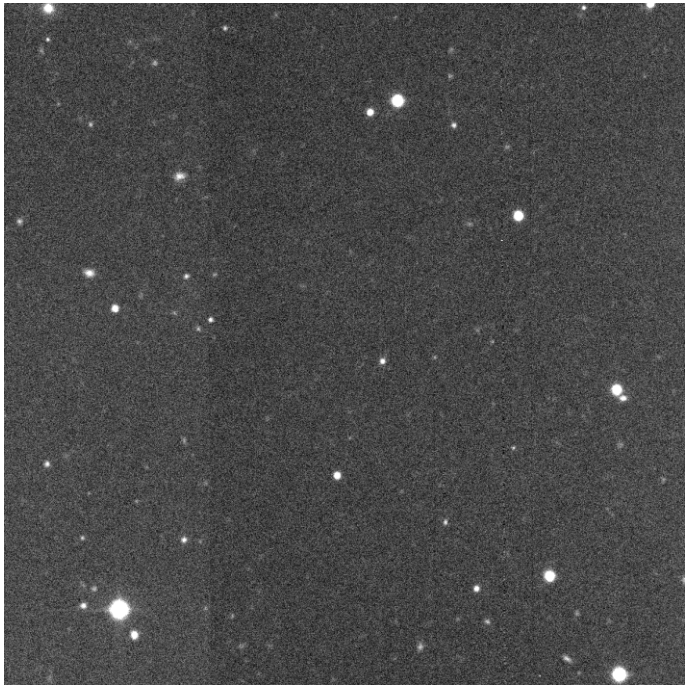
Capture with maximum intensity

TESTS
Set of images with a known supernova



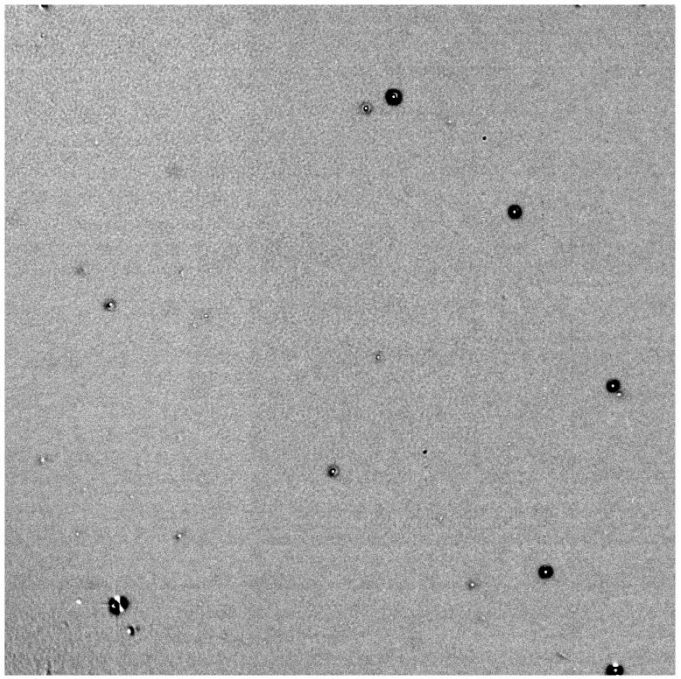
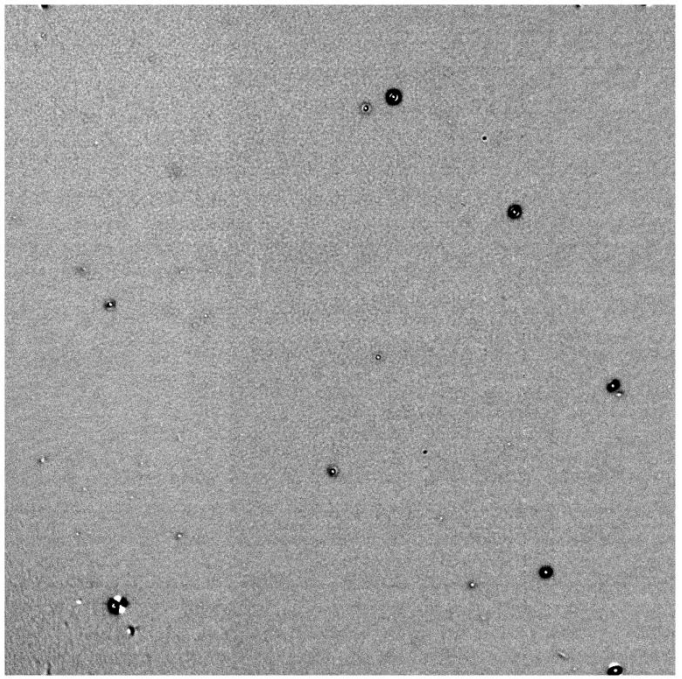
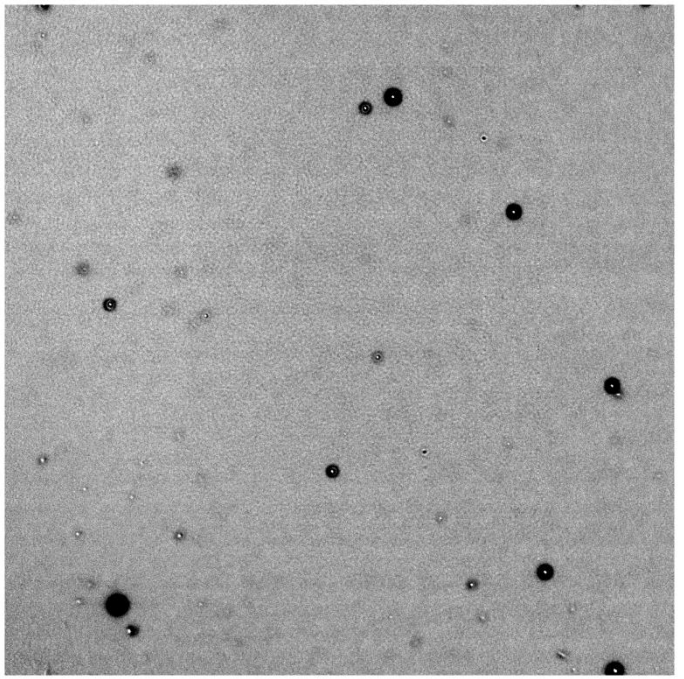
Subtraction with maximum intensity

TESTS
Set of images with a known supernova

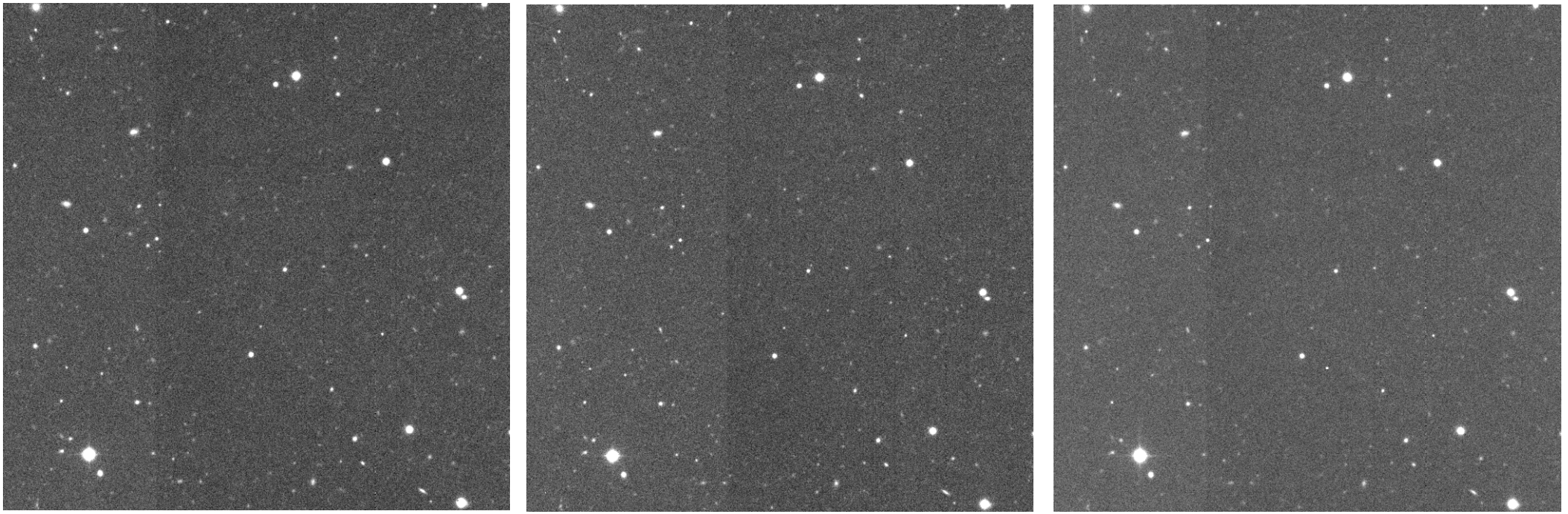
Three captures from previous days

TESTS
Set of images with a known supernova

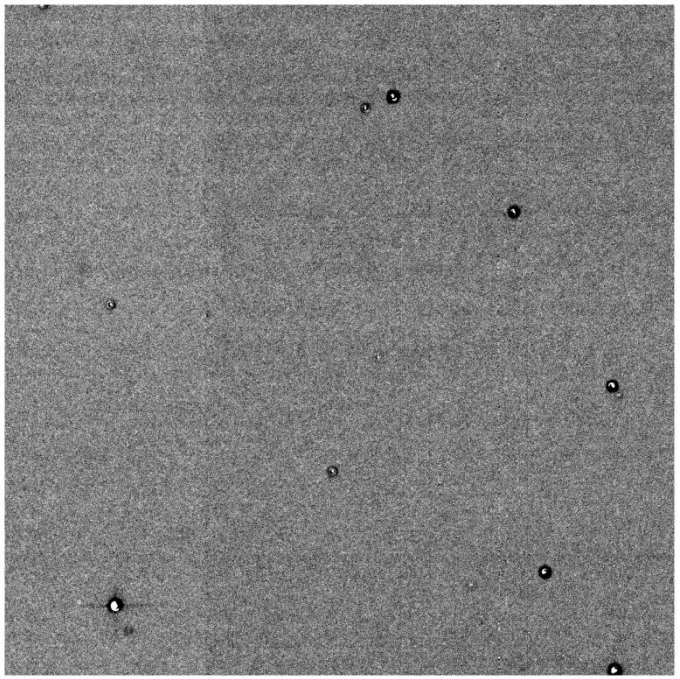
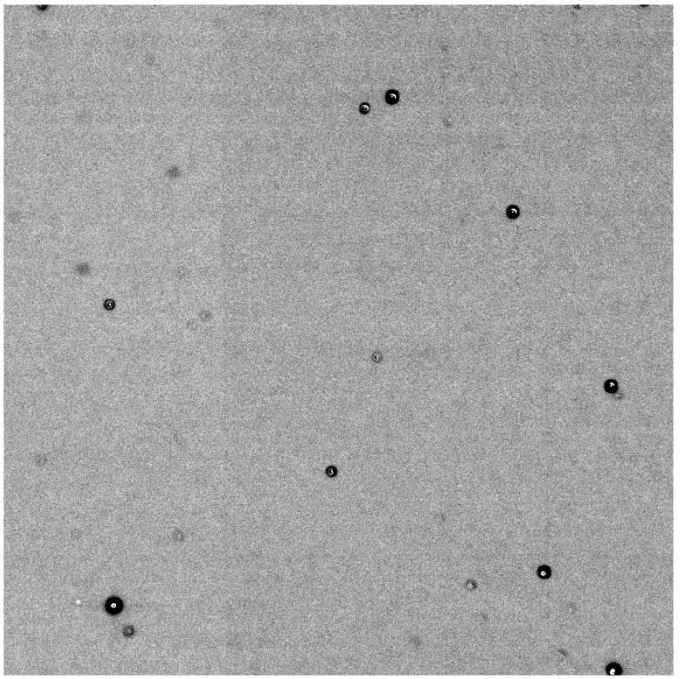
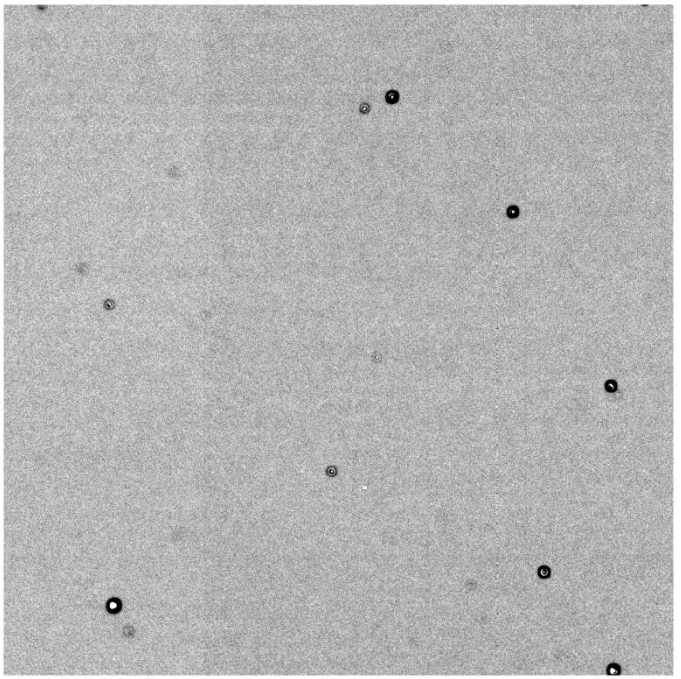
Subtractions from previous days

TESTS
Set of images with a known supernova



Three captures from the next days

TESTS
Set of images with a known supernova

Subtractions from next days

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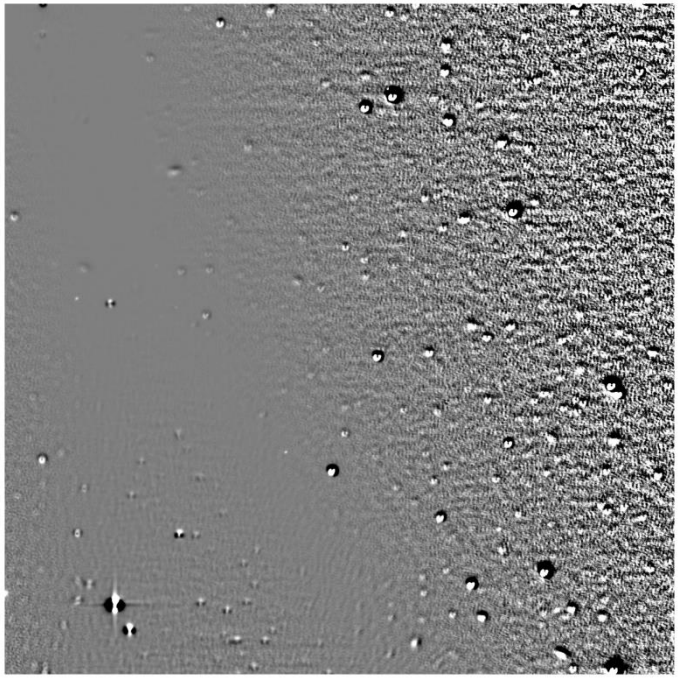
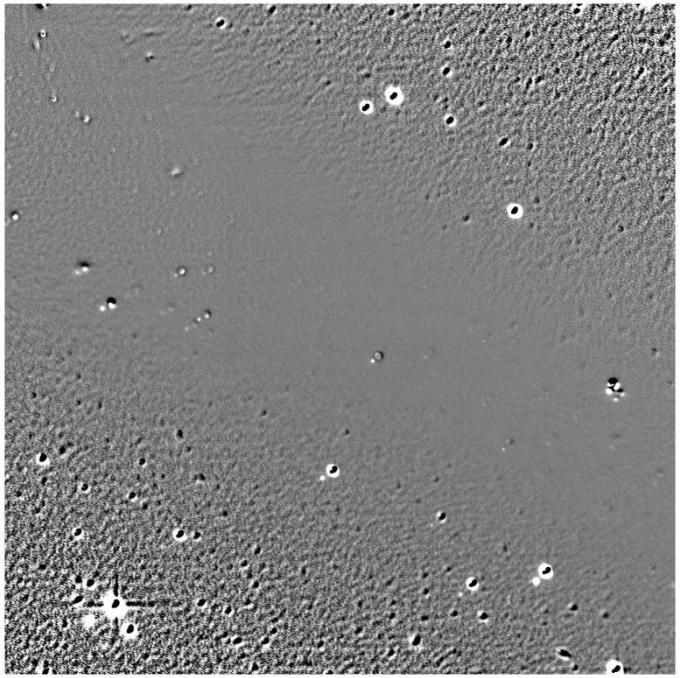
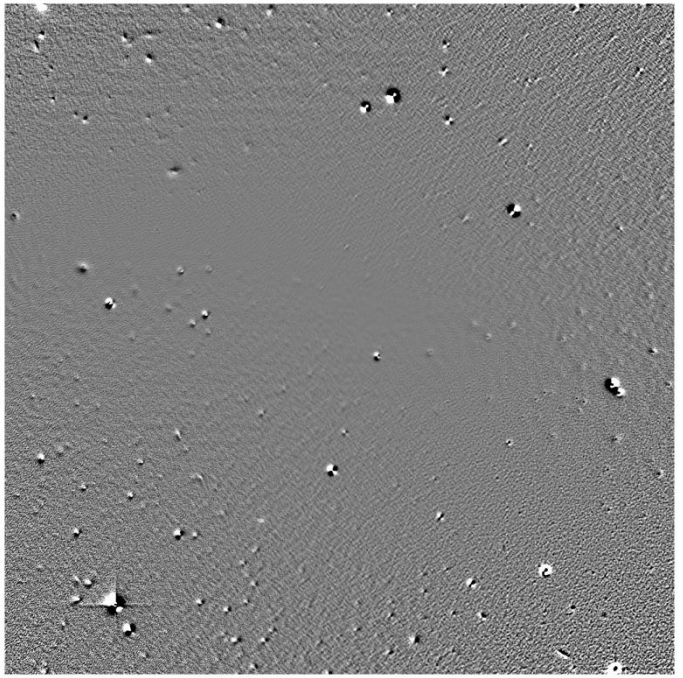
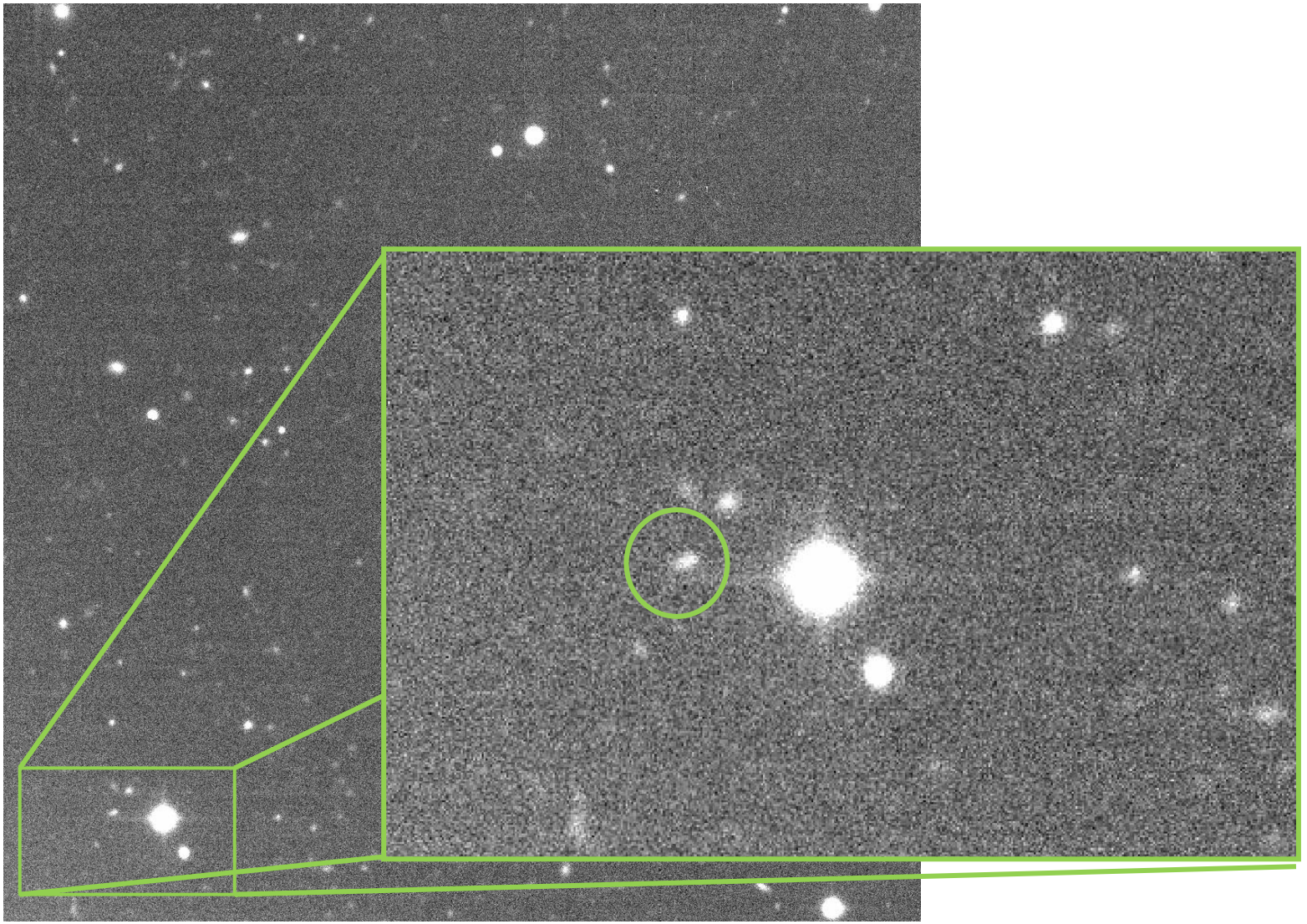
Set of images with a known supernova

Artifacts present in subtractions

TESTS
Set of images with a known supernova



Coaddition of different time

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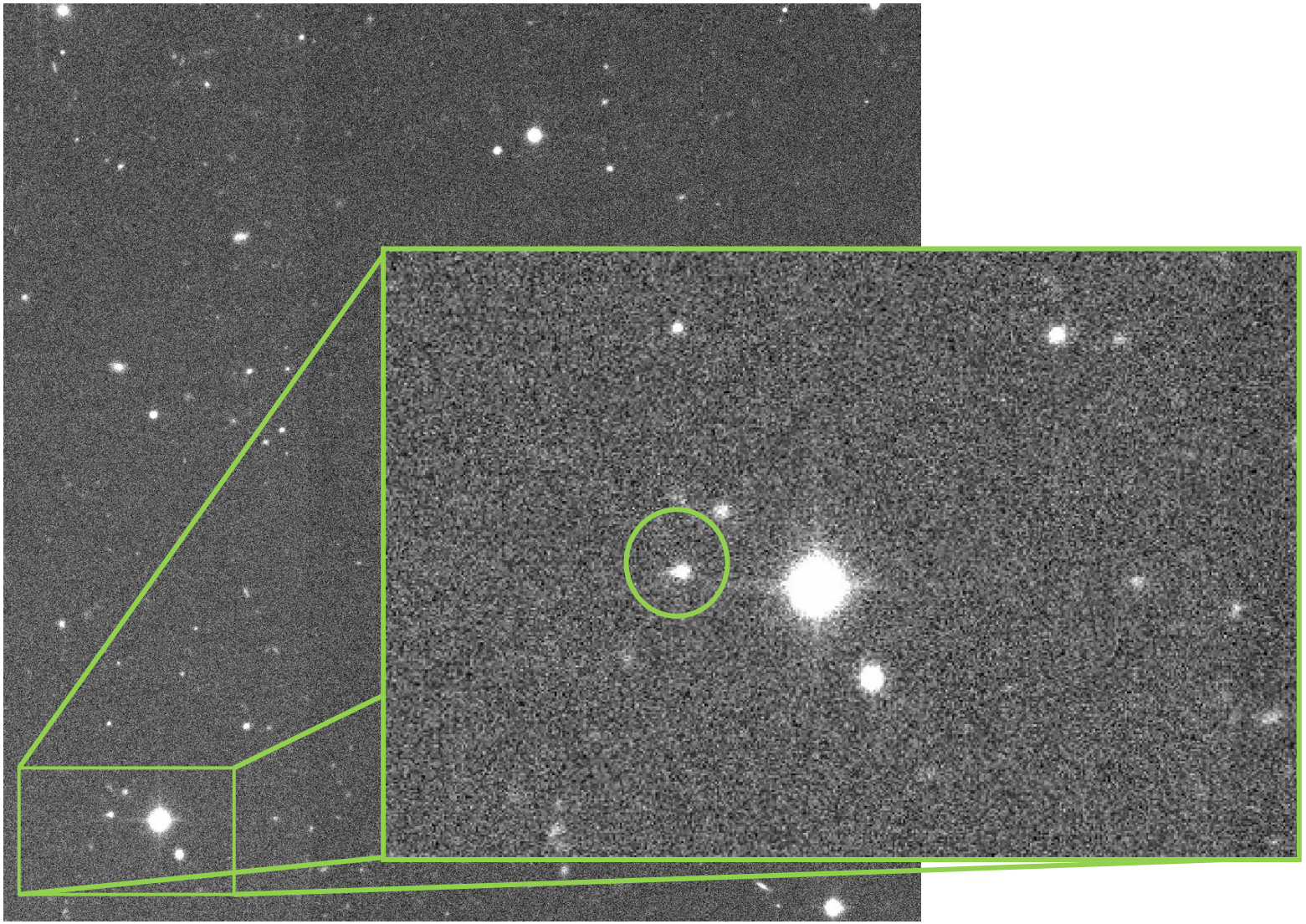
Set of images with a known supernova



Capture with maximum intensity

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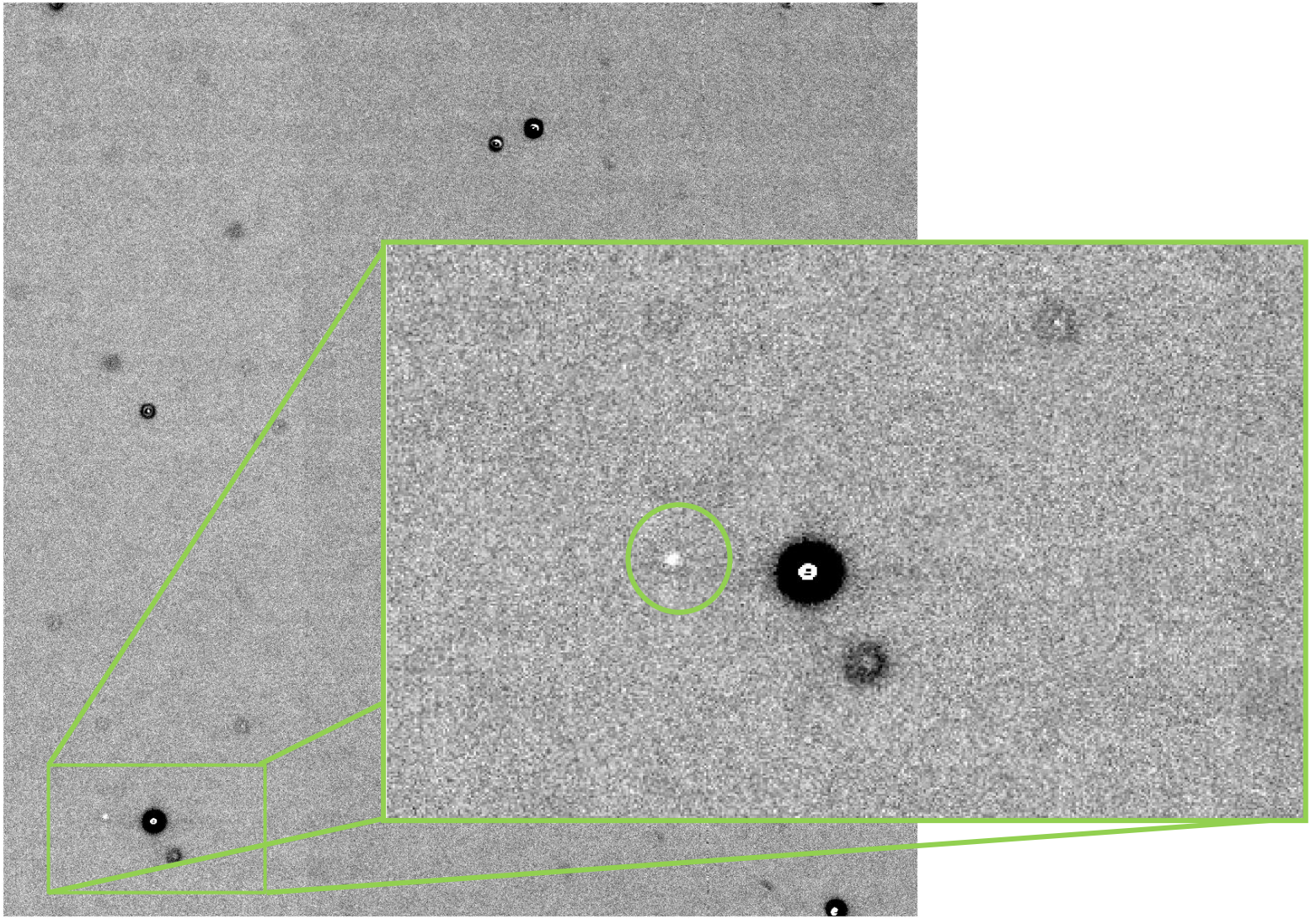
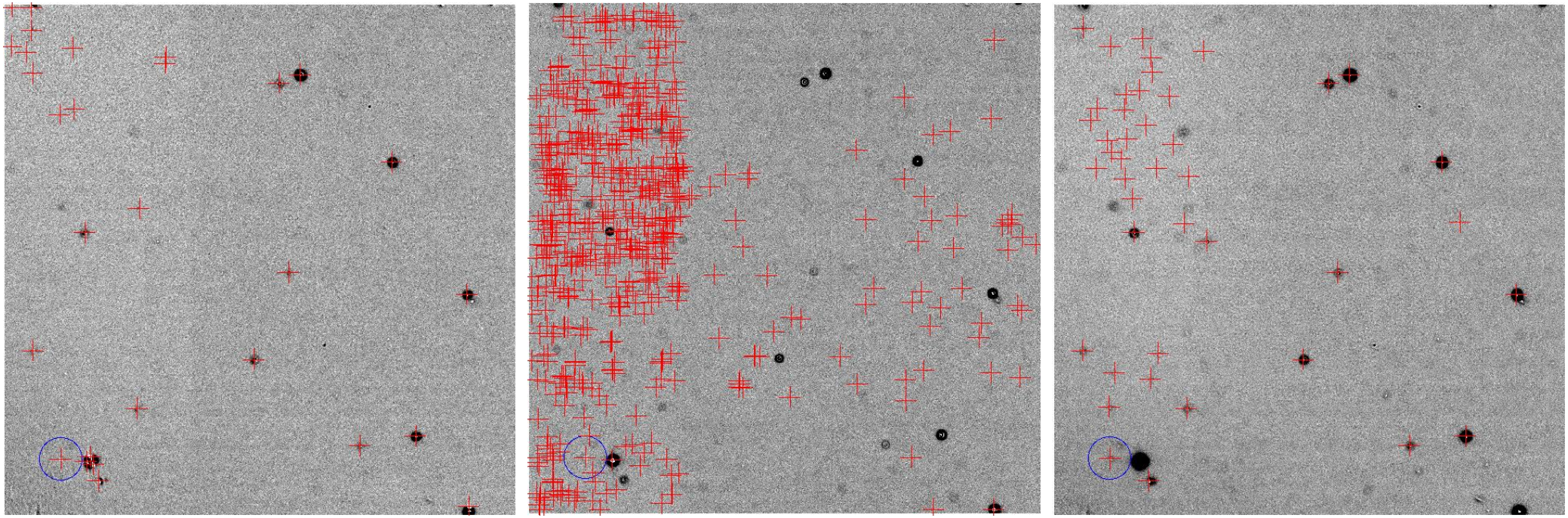
Set of images with a known supernova



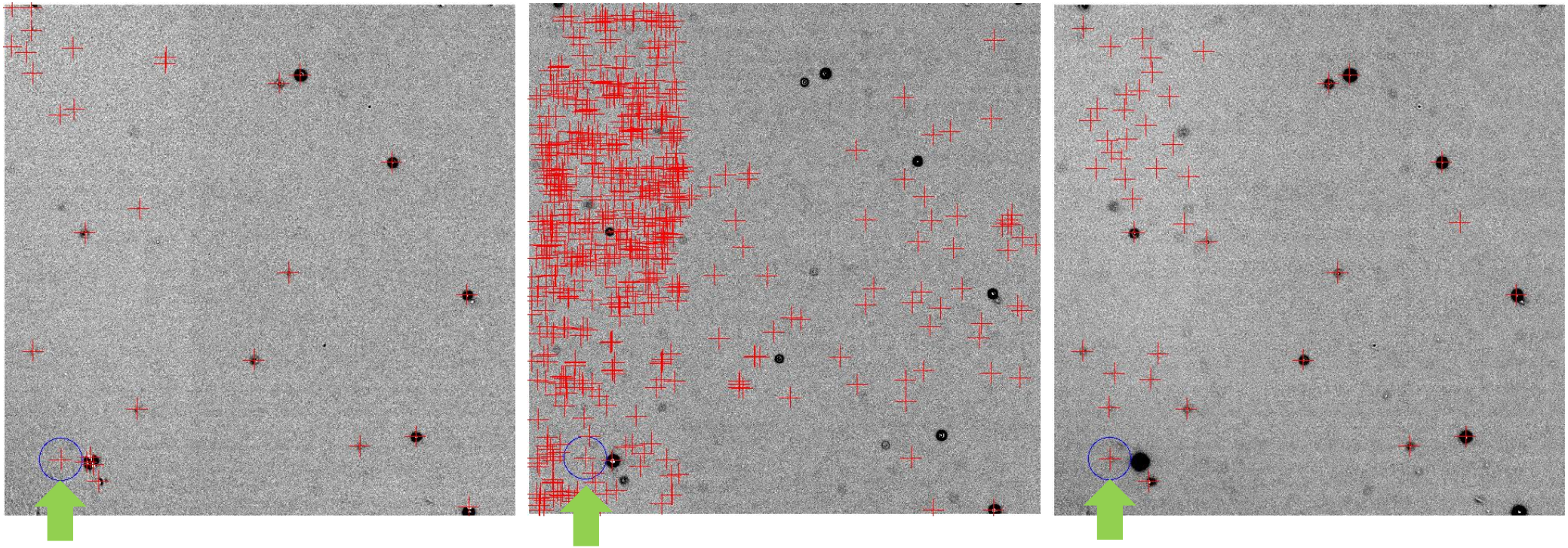
Subtraction with maximum intensity

TESTS
Sources detection with Stack Algorithm



Subtractions from next days

TESTS
Sources detection with Stack Algorithm



Subtractions from next days

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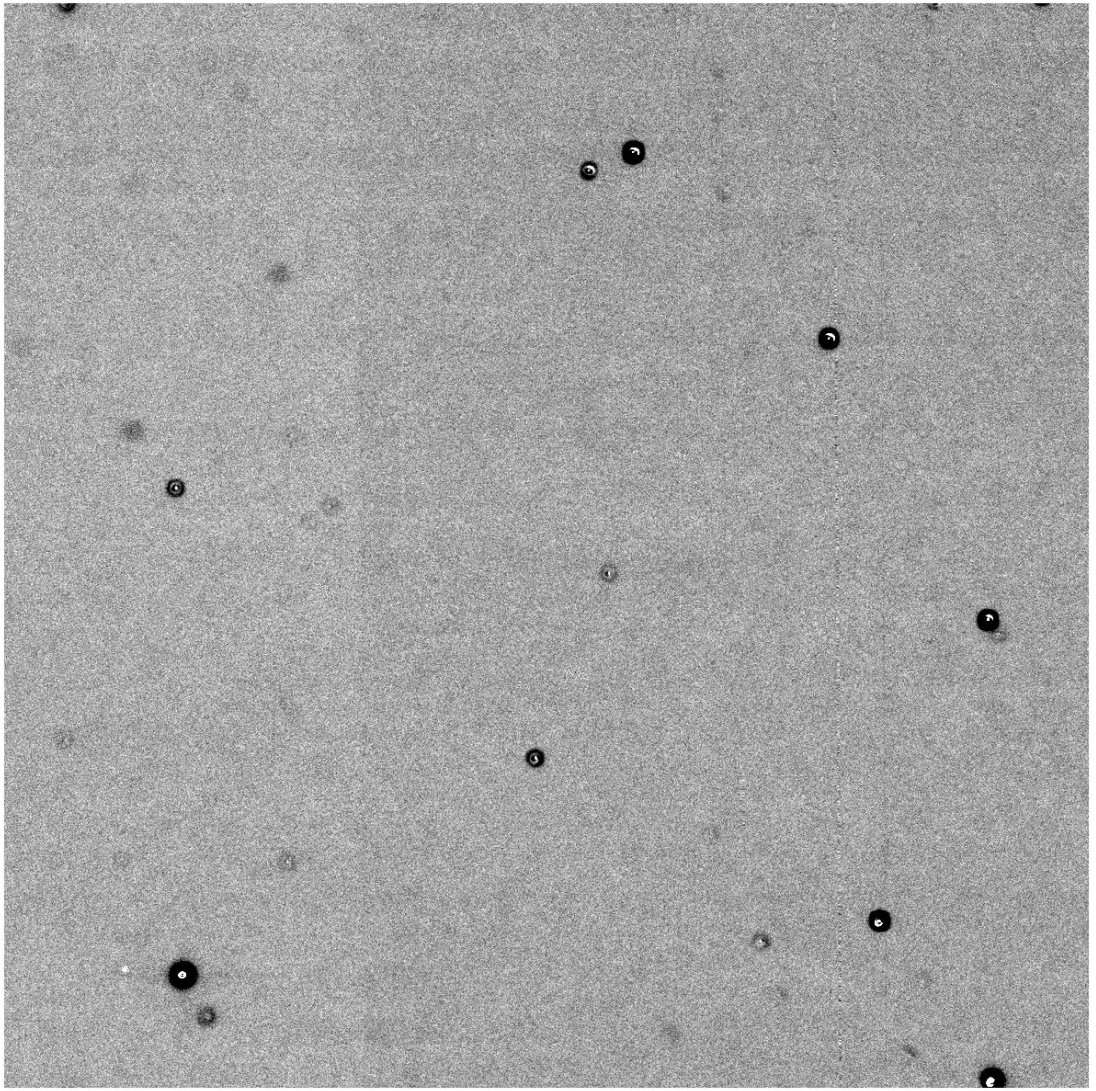
Set of images with a known supernova



Subtraction with maximum intensity

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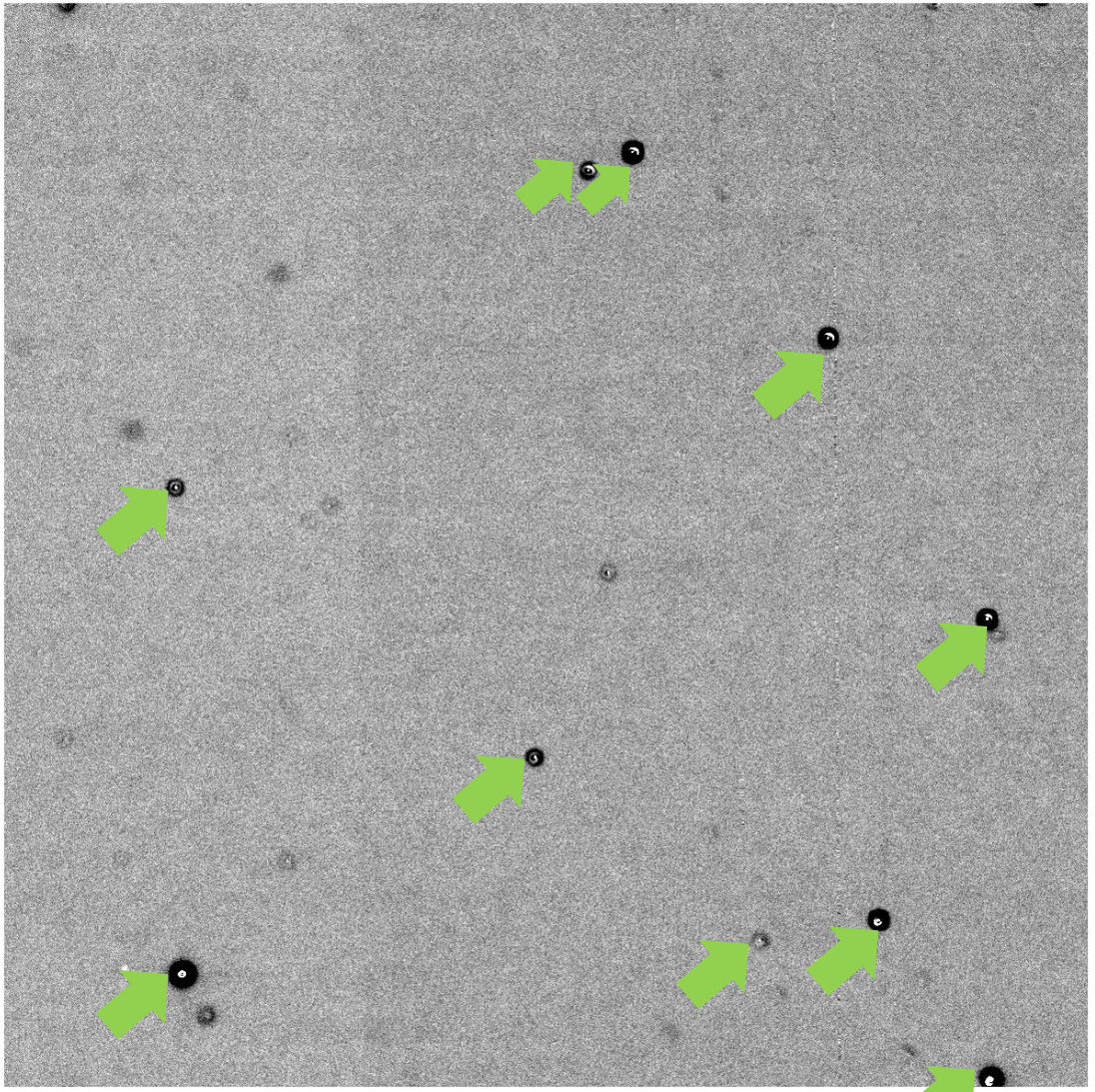
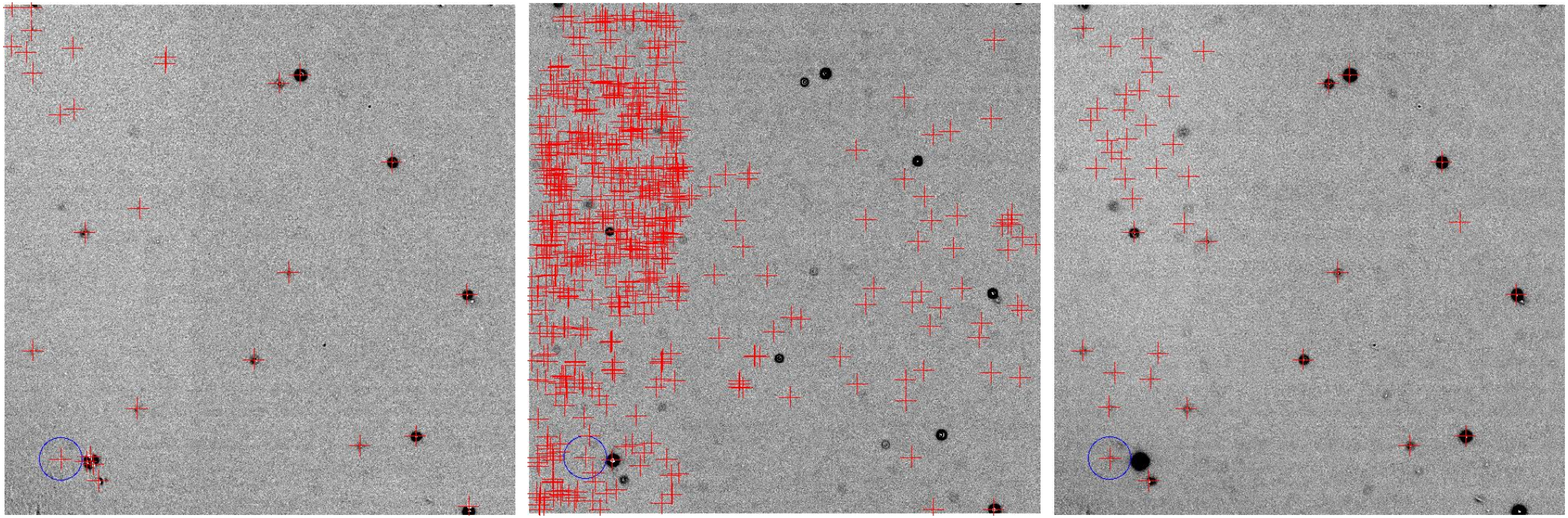
Set of images with a known supernova



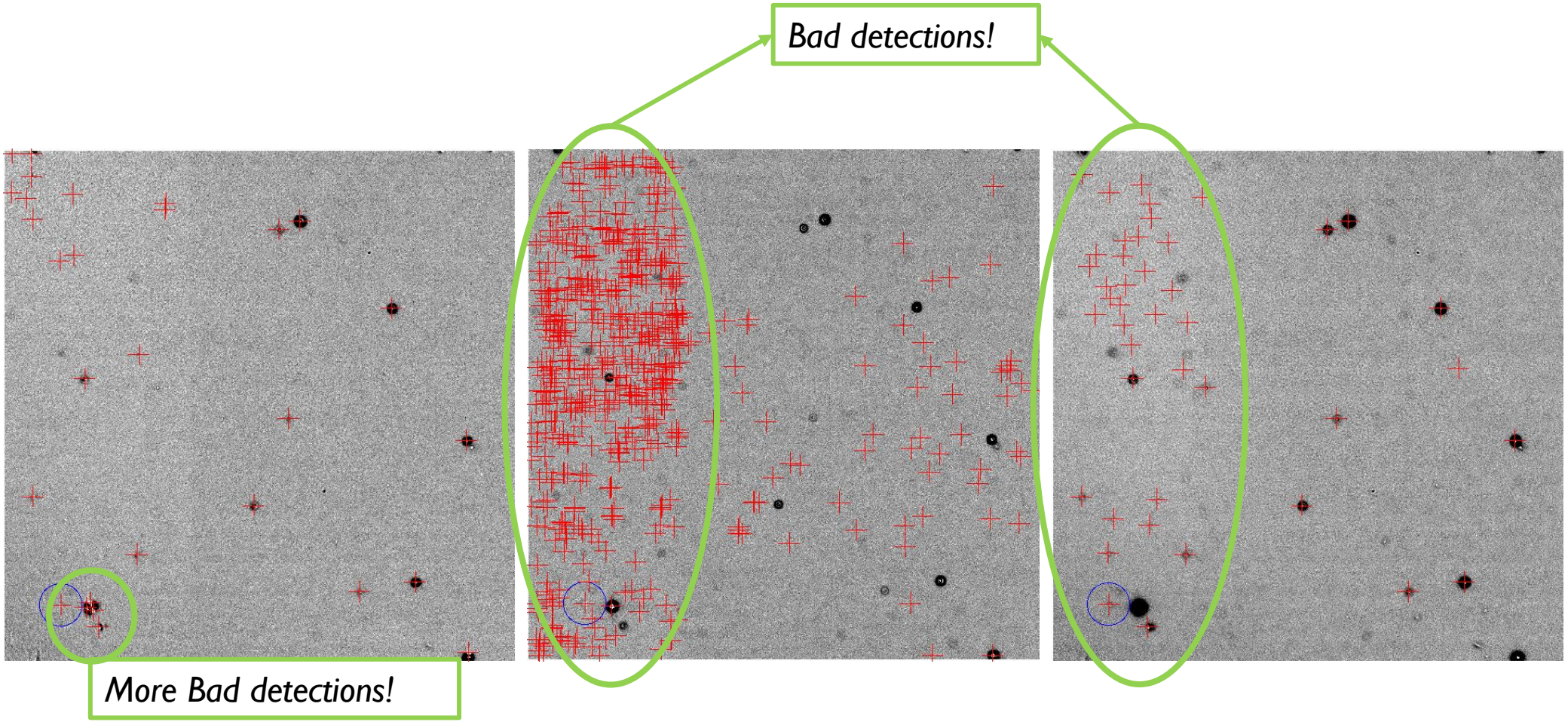
Subtraction with maximum intensity

TESTS
Sources detection with Stack Algorithm



Subtractions from next days

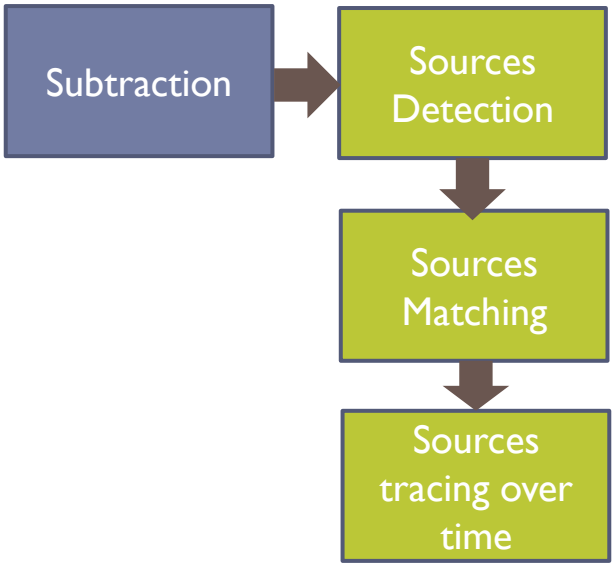
TESTS
Sources detection with Stack Algorithm



Subtractions from next days

WHAT IS MISSING?

- More tests of robustness are necessary in order to ensure the reach of the LSST algorithms.
- Also, more tests of calculation time, to ensure efficiency for the processing.



Challenges

Problem	Proposal
Subtraction algorithm has also numerous artifacts to be addressed	Correct and improve the subtraction algorithm. Address problems of normalization/PSF-matching if present.
Number of false detections is still considerable.	Correct and improve algorithms to reduce the number of false detections.
There is no transient/variable classification algorithm implemented.	Implement a shape recognition processing algorithm using machine learning.
There is still work to do regarding the use of the algorithms for high volumes of data.	Run tests with high volumes of data. Benchmark and use the results to improve the code.