Image subtraction and transient detection with LSST Software

By Juan Pablo REYES GOMEZ
Supervisors: Dominique FOUCHEZ and Marcela HERNANDEZ

Outline

- Methodology
- Image Subtraction with PSF Matching
- Tests on Image Subtraction
- Light Curves
- Image Quality and Artifacts
- Other Tests
- Conclusions
- Challenges

Outline

- Methodology
- Image Subtraction with PSF Matching
- Tests on Image Subtraction
- Light Curves
- Image Quality and Artifacts
- Other Tests
- Conclusions
- Challenges

Methodology

All the present work has been done using iPython notebooks. The pipeline functions were isolated and can be easily used from the notebooks in a more transparent way (for the developer).

These are some of the notebooks used:

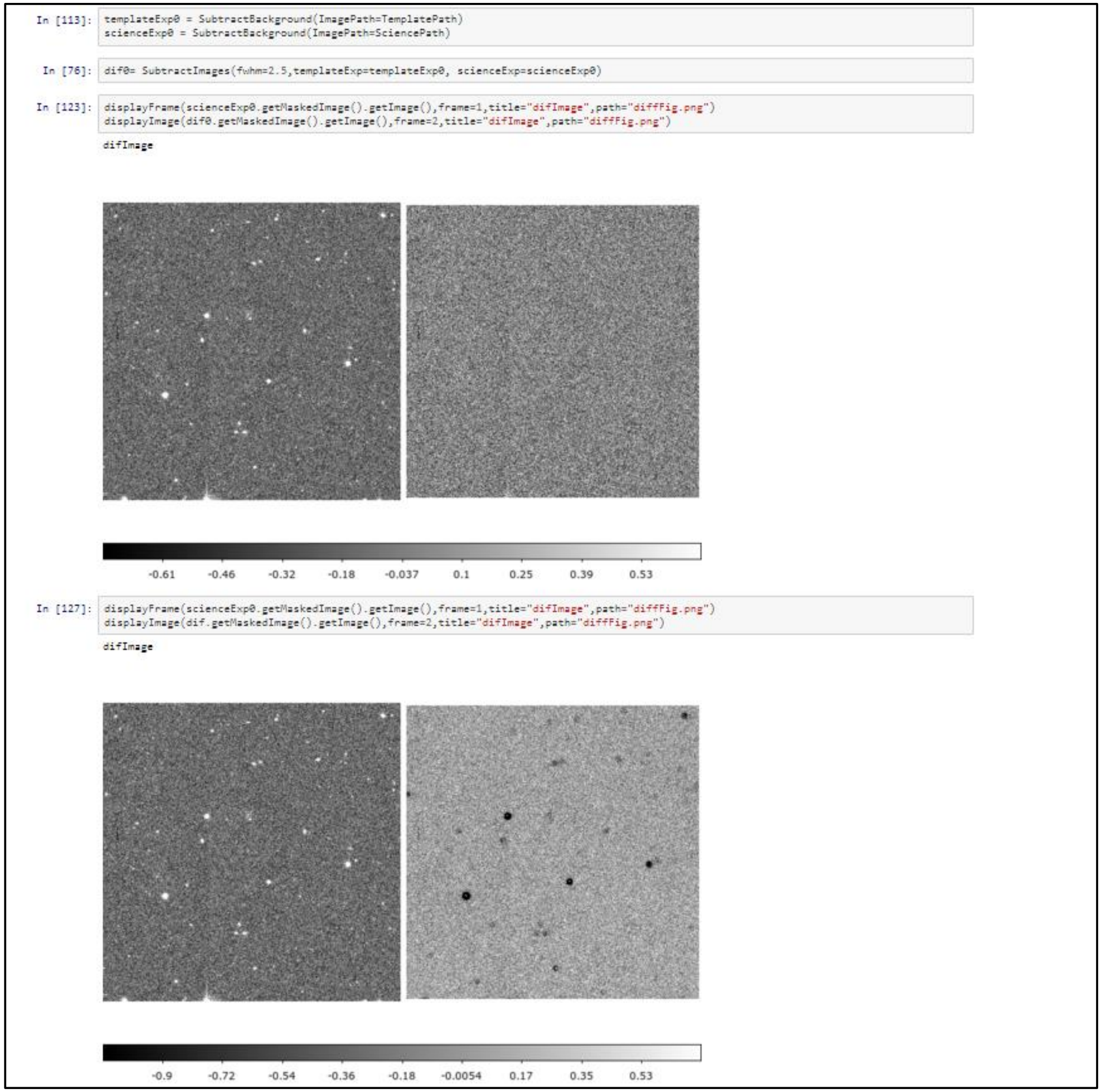
https://github.com/Daraexus/Subtraction_Notebooks/blob/master/Subtraction_on_patch.ipynb

https://github.com/Daraexus/Subtraction_Notebooks/blob/master/Coaddition_for_subtraction.ipynb

http://nbviewer.ipython.org/github/DominiqueFouchez/Subtraction_Notebooks/blob/master/Subtraction_on_patch.ipynb

http://nbviewer.ipython.org/github/DominiqueFouchez/Subtraction_Notebooks/blob/Coaddition_for_subtraction.ipynb

Methodology



Every function is called from Python and the results are shown on the notebook directly using ds9 and matplotlib.

Methodology

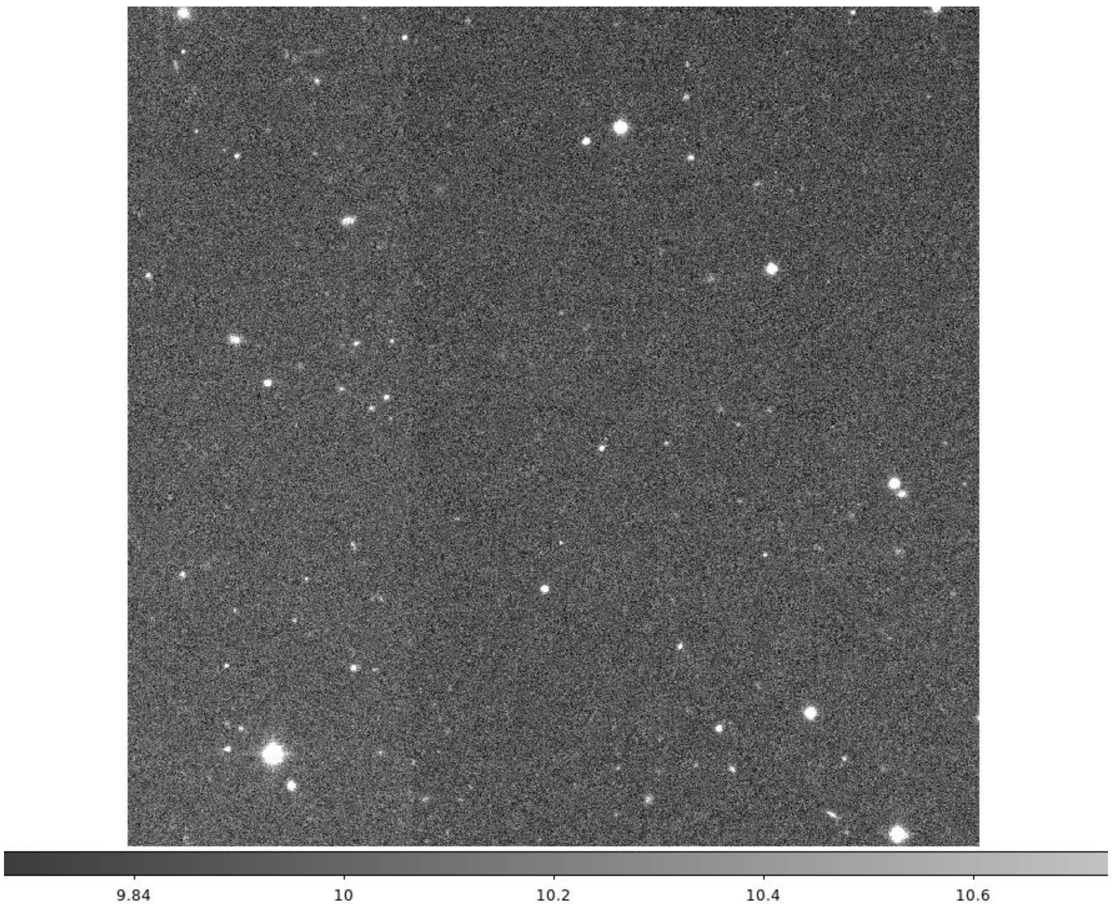
```python
def SubtractImages(fwhm=None, templateExp=None, scienceExp=None):
    config = ipDiffim.ImagePsfMatchTask.ConfigClass()
    #Kernel name is Alard-Lupton by default
    config.kernel.name = "AL"
    subconfig = config.kernel.active
    #Fwhm will be calculated if none is provide
    defFwhm         = fwhm
    fwhmS = defFwhm
    fwhmT = defFwhm
    psfmatch = ipDiffim.ImagePsfMatchTask(config)

    results  = psfmatch.subtractExposures(templateExp, scienceExp,
                            templateFwhmPix = fwhmT, scienceFwhmPix = fwhmS, doWarping=True)

    differenceExposure = results.subtractedExposure


    return differenceExposure
```

In the Python Notebook we can mix pipeline code in Python with other classes defined in Stack (depending on the desired complexity level).

Outline

- Methodology
- Image Subtraction with PSF Matching
- Tests on Image Subtraction
- Light Curves
- Image Quality and Artifacts
- Other Tests
- Conclusions
- Challenges

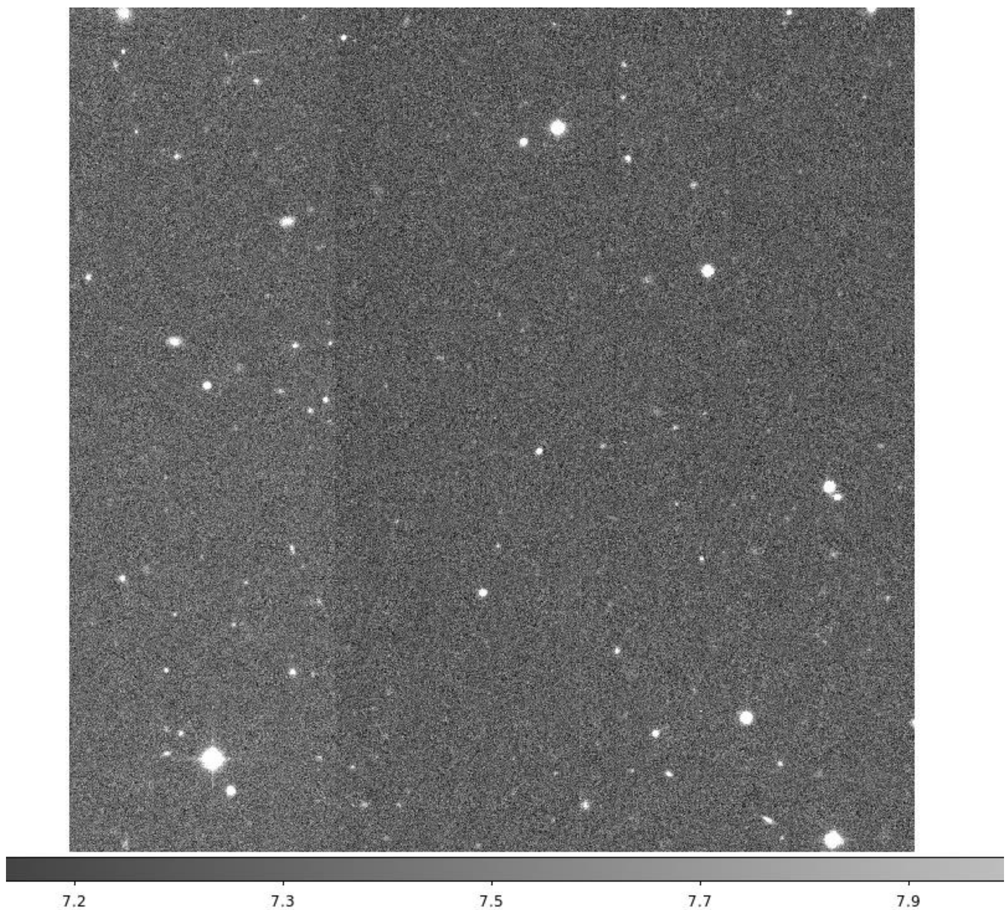
Image Subtraction with PSF Matching



Science Exposure with a known supernova present.

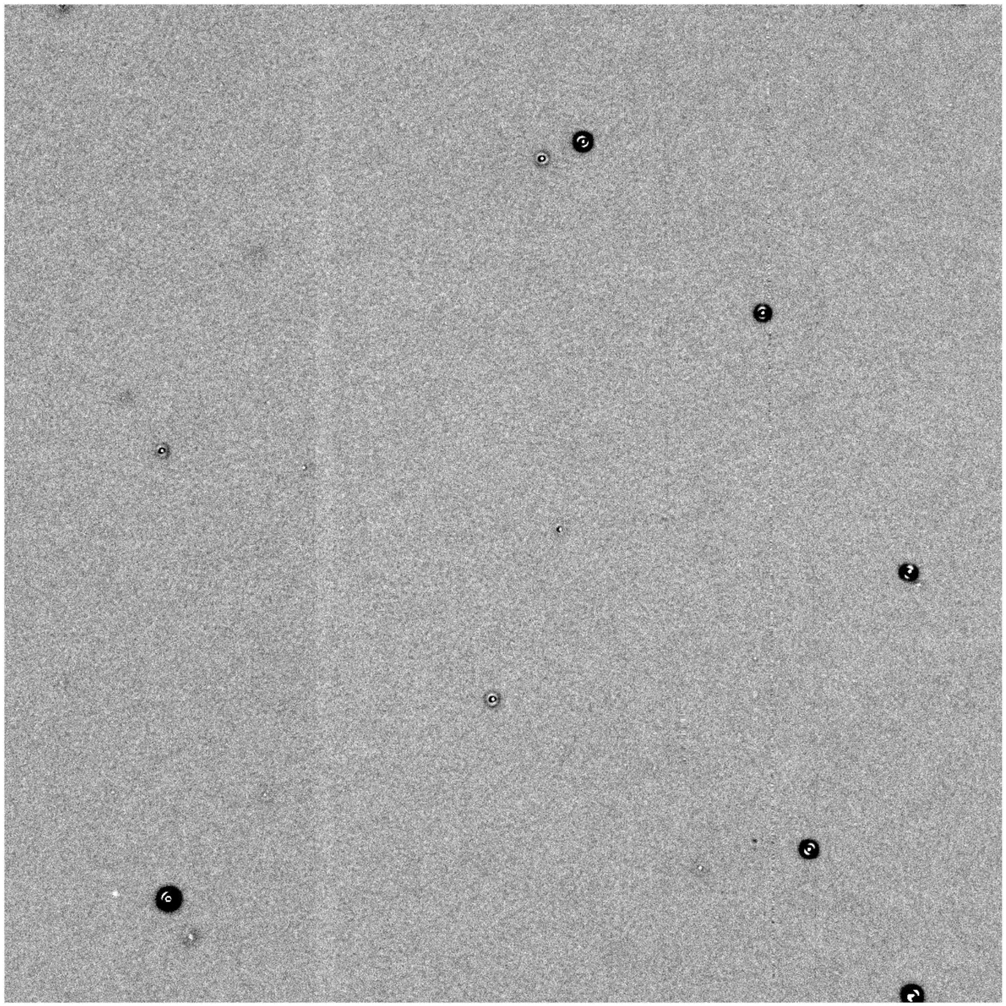
This image corresponds to one visit on 02/06/2005.

Image Subtraction with PSF Matching



Template Exposure with a set of coadded images from 2008 (five visits from the same day).

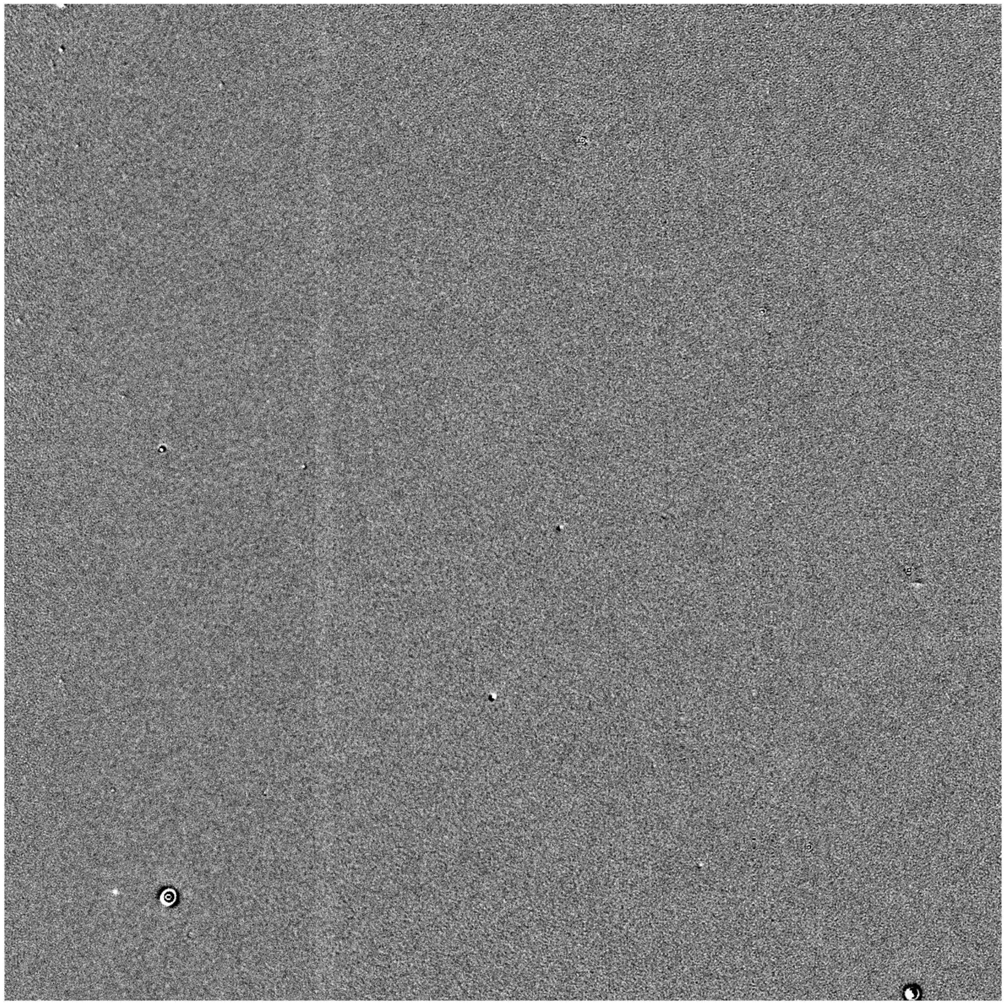
Image Subtraction with PSF Matching



Subtracted Result Image using the PSF-matching method.

This was a typical result as shown on the last meeting: bad subtractions.

Image Subtraction with PSF Matching

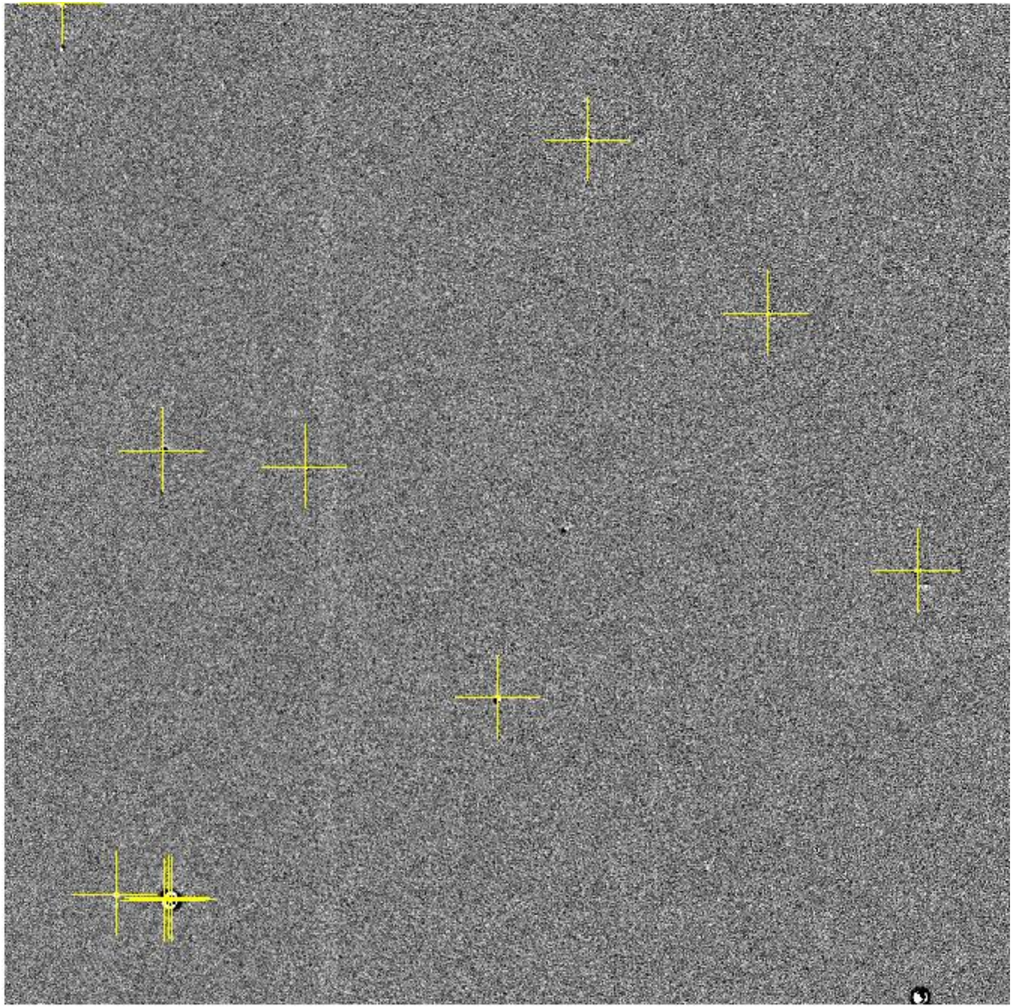


Subtracted Result Image using the PSF-matching method.

This is a subtracted image after performing always a background subtraction.

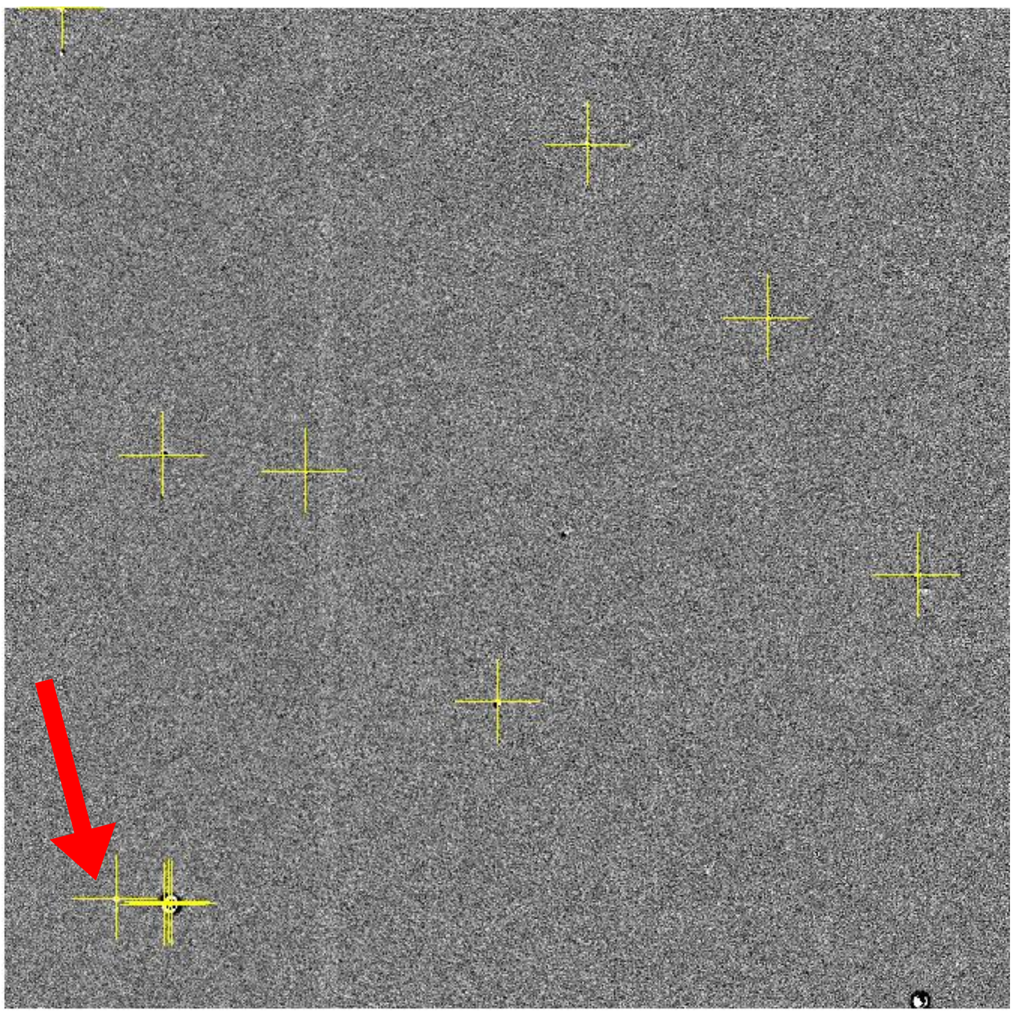
Subtraction method doesn't assert this precondition, even when the quality of the results is highly impacted by background noise.

Image Subtraction with PSF Matching



Source detection for the subtracted image, (with PSF-matching), using the original DETECTED mask calculated on the processCCD function.

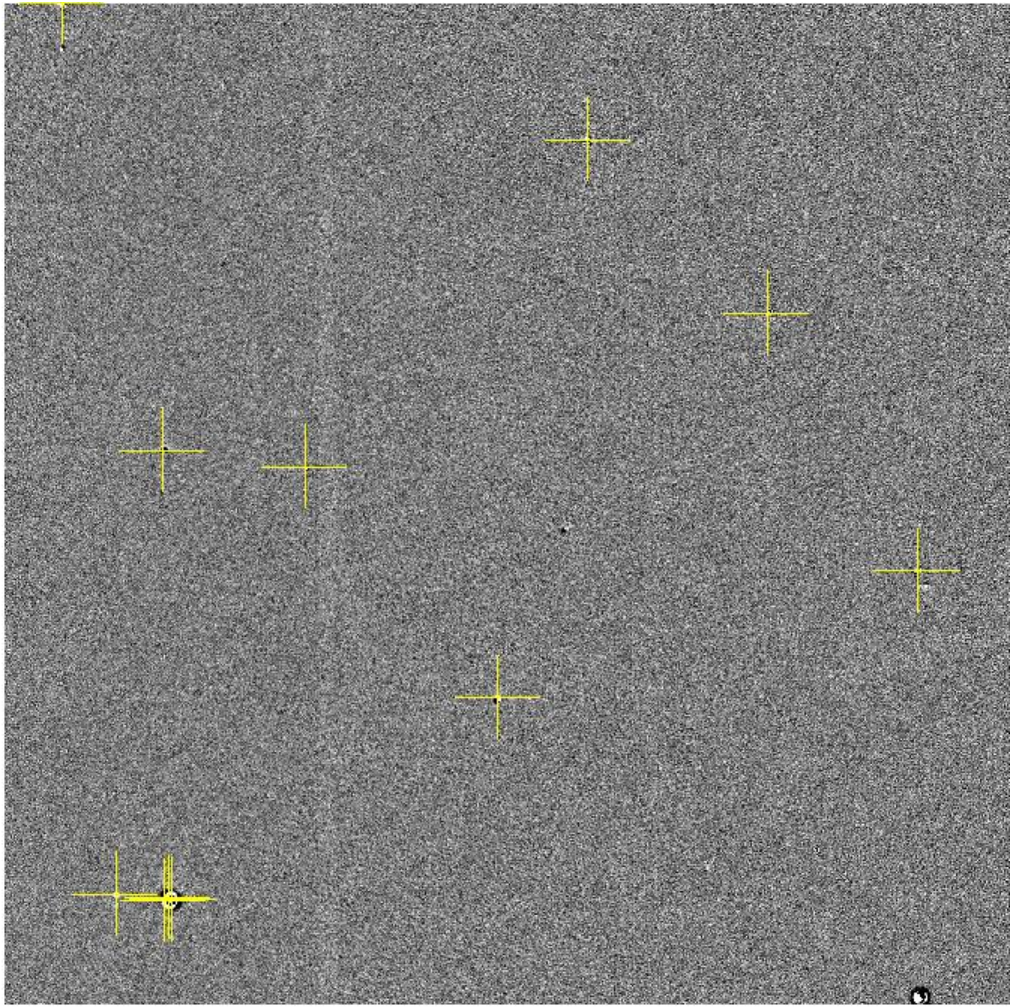
Image Subtraction with PSF Matching



Source detection for the subtracted image (with PSF-matching), using the original DETECTED mask calculated on the processCCD function.

The supernova was detected!

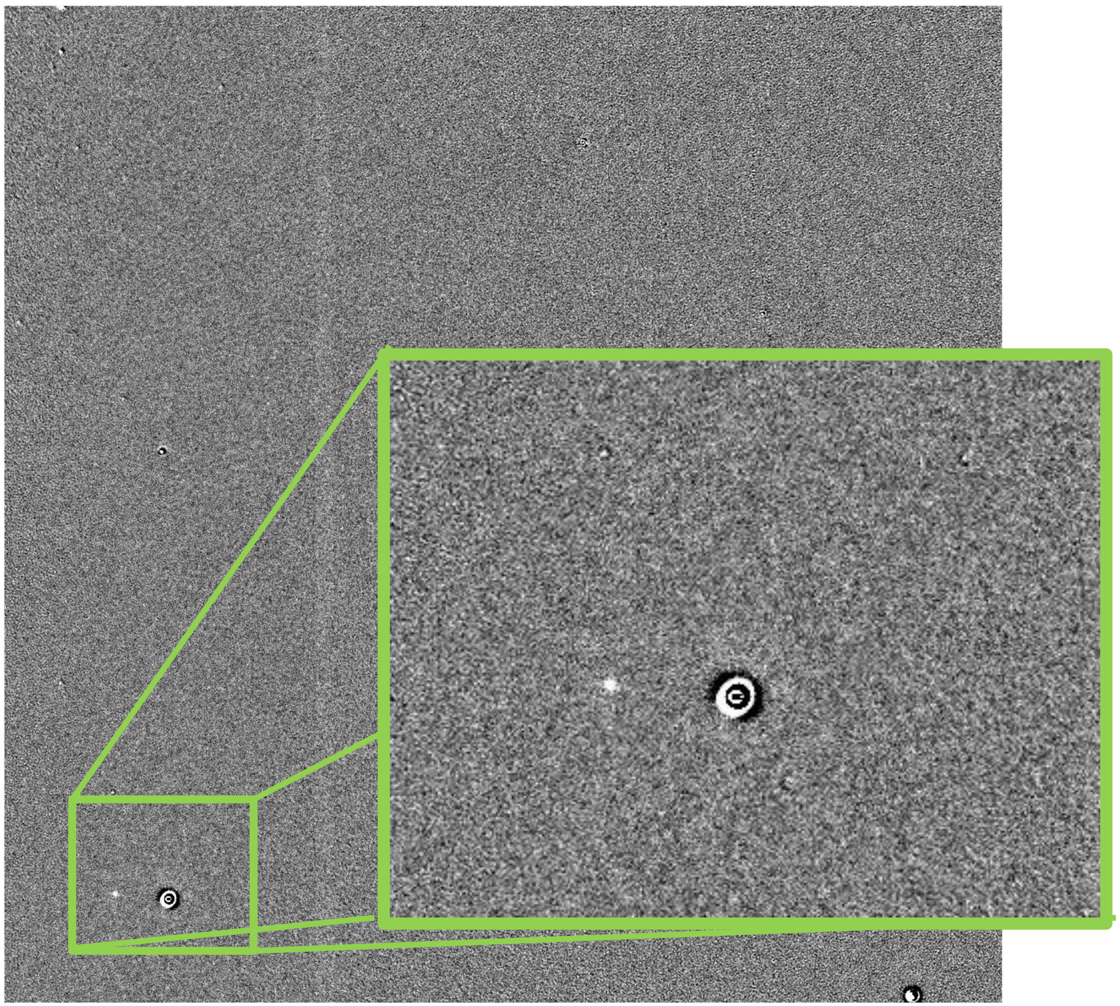
Image Subtraction with PSF Matching



Source detection for the subtracted image, (with PSF-matching), using the original DETECTED mask calculated on the processCCD function.

8 other sources were detected (sources belonging to the bad residual at bottom don't count).

Image Subtraction with PSF Matching

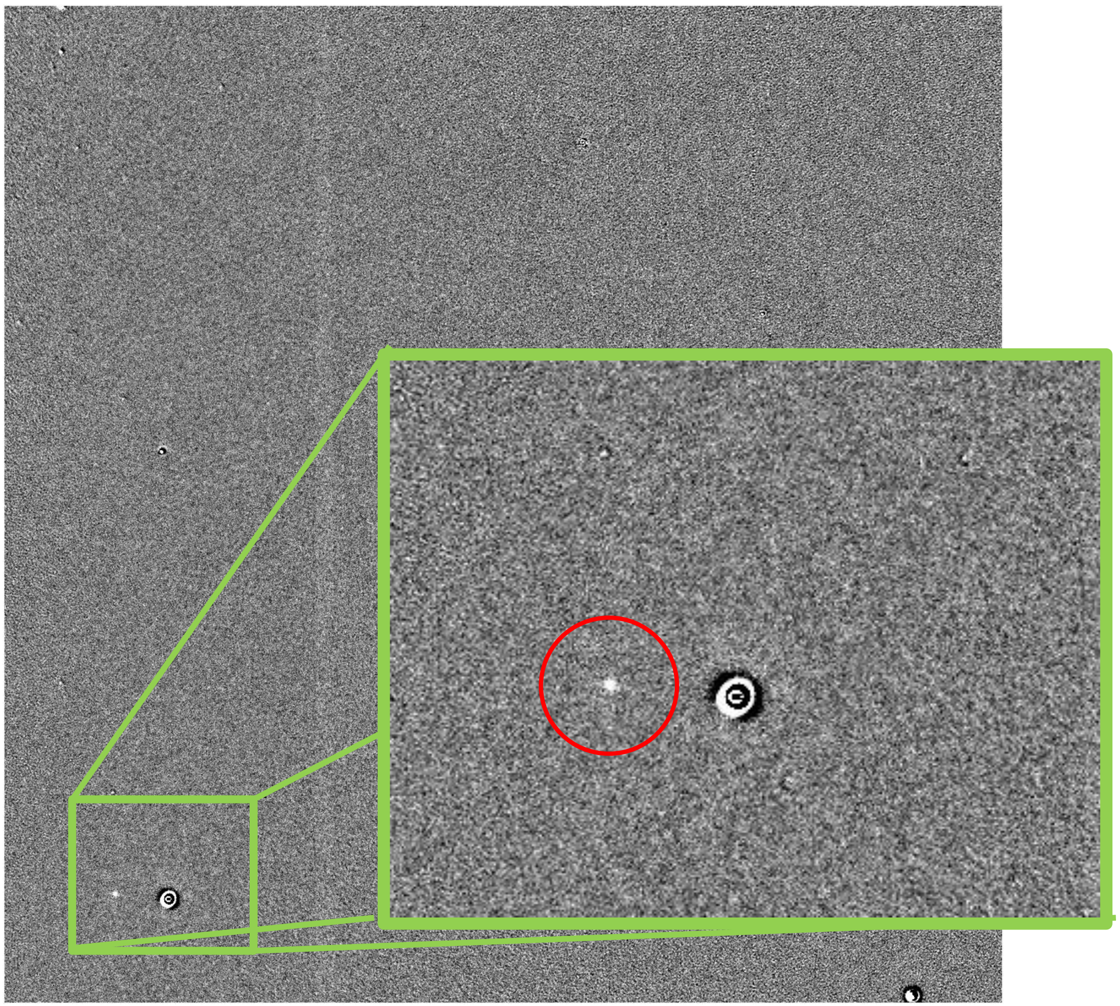


Subtracted Result Image using the PSF-matching method.

This is a subtracted image after performing <u>always</u> a background subtraction.

Subtraction method doesn't assert this precondition, even when the quality of the results is highly impacted by background noise.

Image Subtraction with PSF Matching



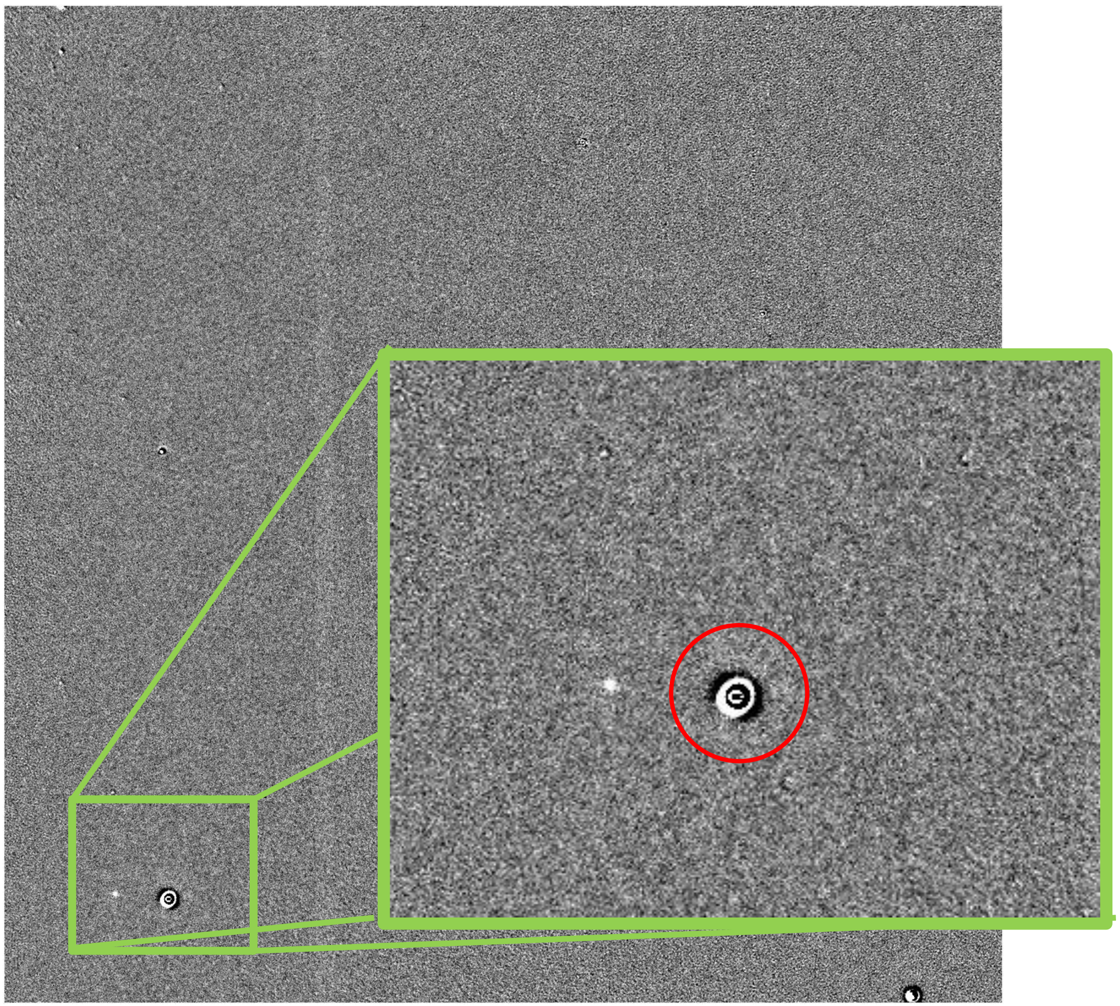
Supernova detected!

Subtracted Result Image using the PSF-matching method.

This is a subtracted image after performing <u>always</u> a background subtraction.

Subtraction method doesn't assert this precondition, even when the quality of the results is highly impacted by background noise

Image Subtraction with PSF Matching



Subtracted Result Image using the PSF-matching method.

This is a subtracted image after performing always a background subtraction.

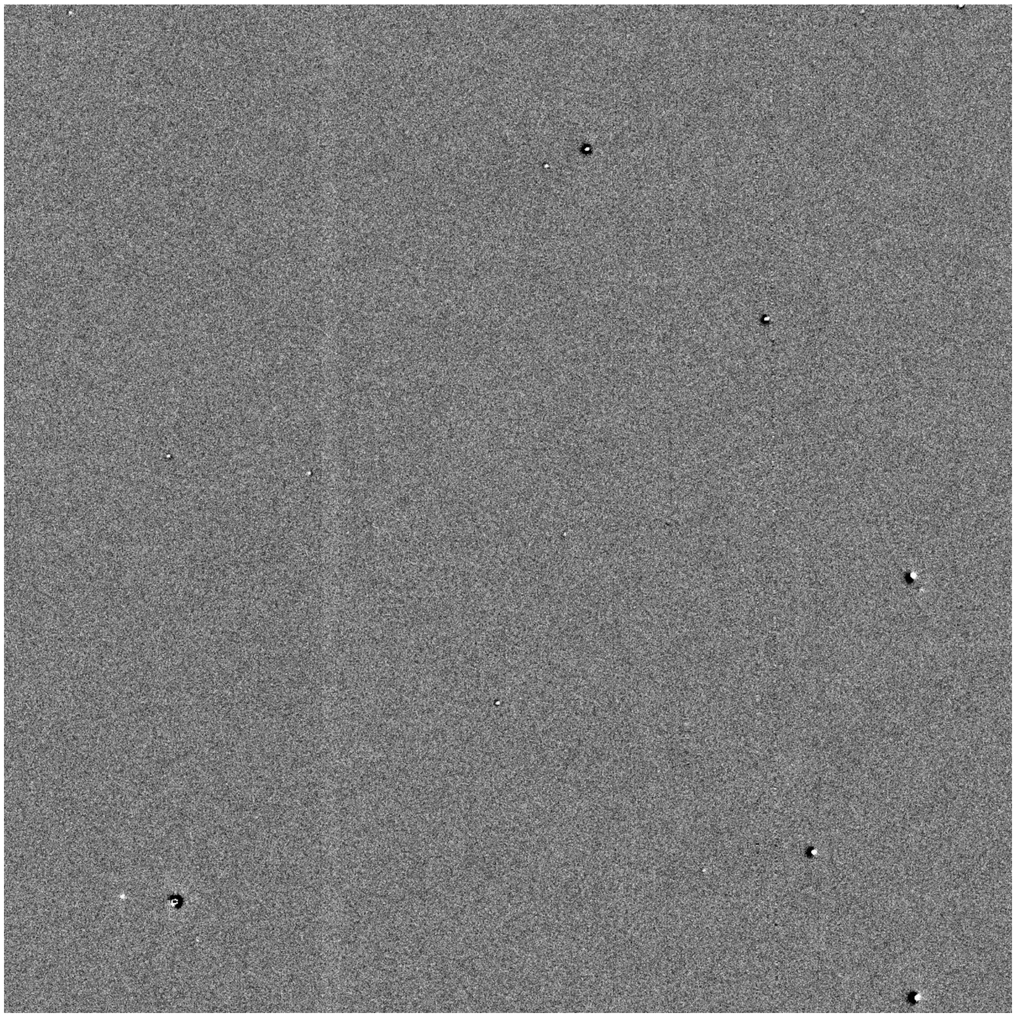
Subtraction method doesn't assert this precondition, even when the quality of the results is highly impacted by background noise

Bad source subtraction!

Outline

- Methodology
- Image Subtraction with PSF Matching
- Tests on Image Subtraction
- Light Curves
- Image Quality and Artifacts
- Other Tests
- Conclusions
- Challenges

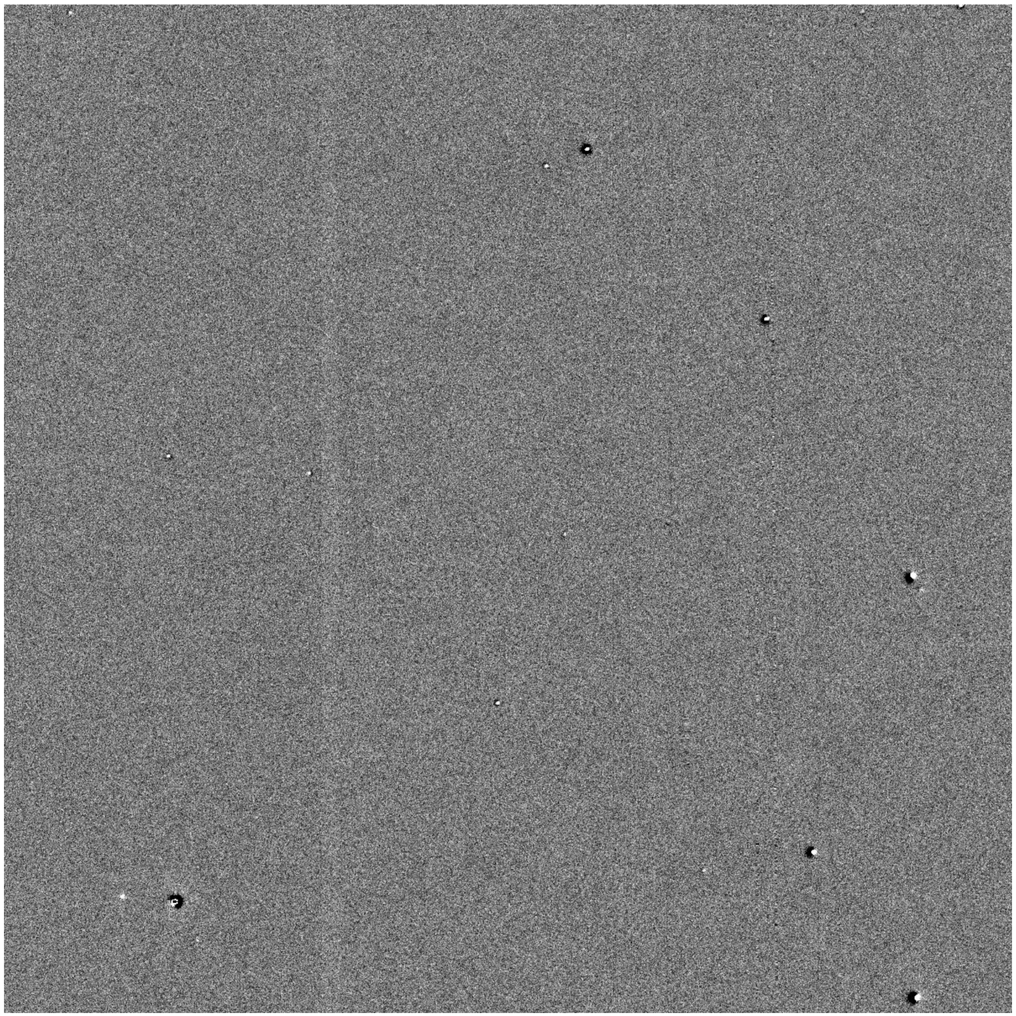
Tests on Image Subtraction



Subtracted Image without using PSF-Match (pixel-wise subtraction).

- The background was subtracted previously.
- The image was calculated faster.
- Is there a considerable increment on the false detections?

Tests on Image Subtraction

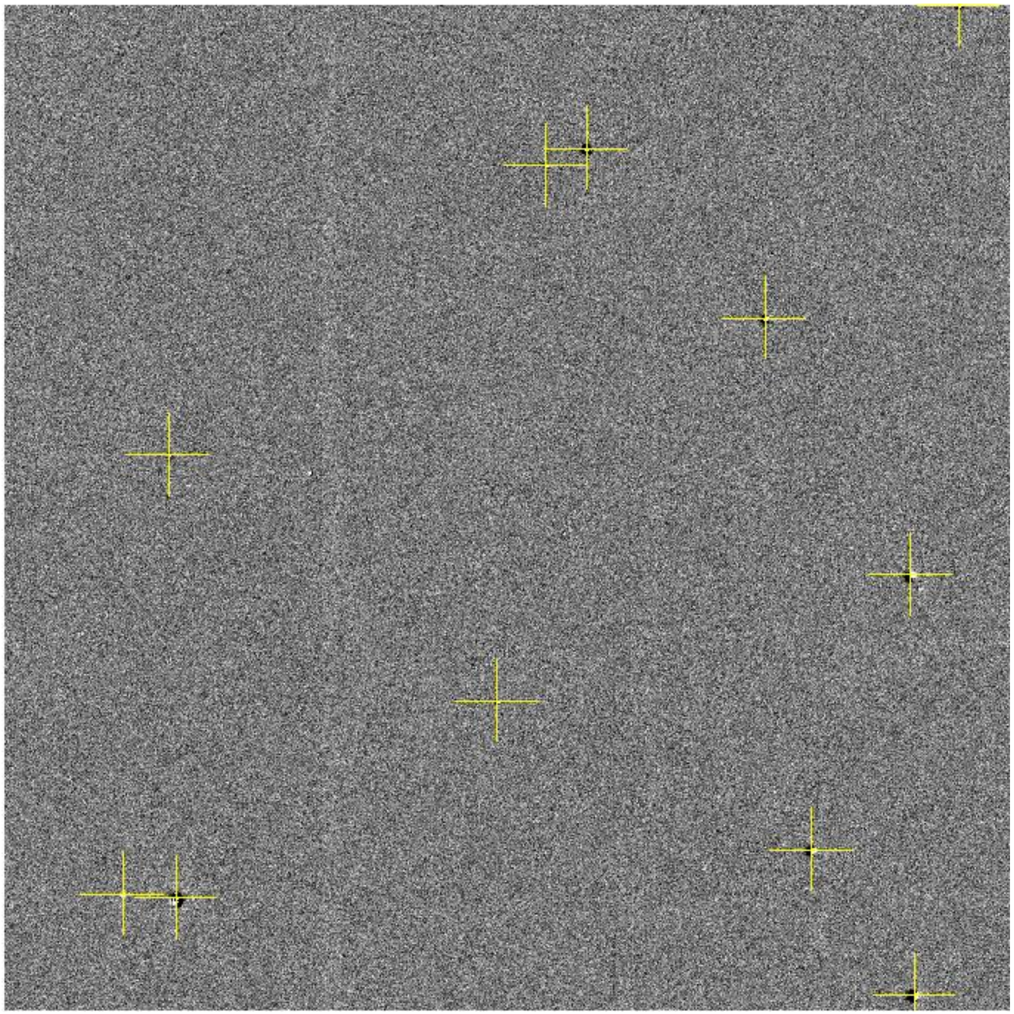


Subtracted Image without using PSF-Match (pixel-wise subtraction).

More problematic subtraction residuals are present in this image.

Will it have more false-positives when trying to detect sources?

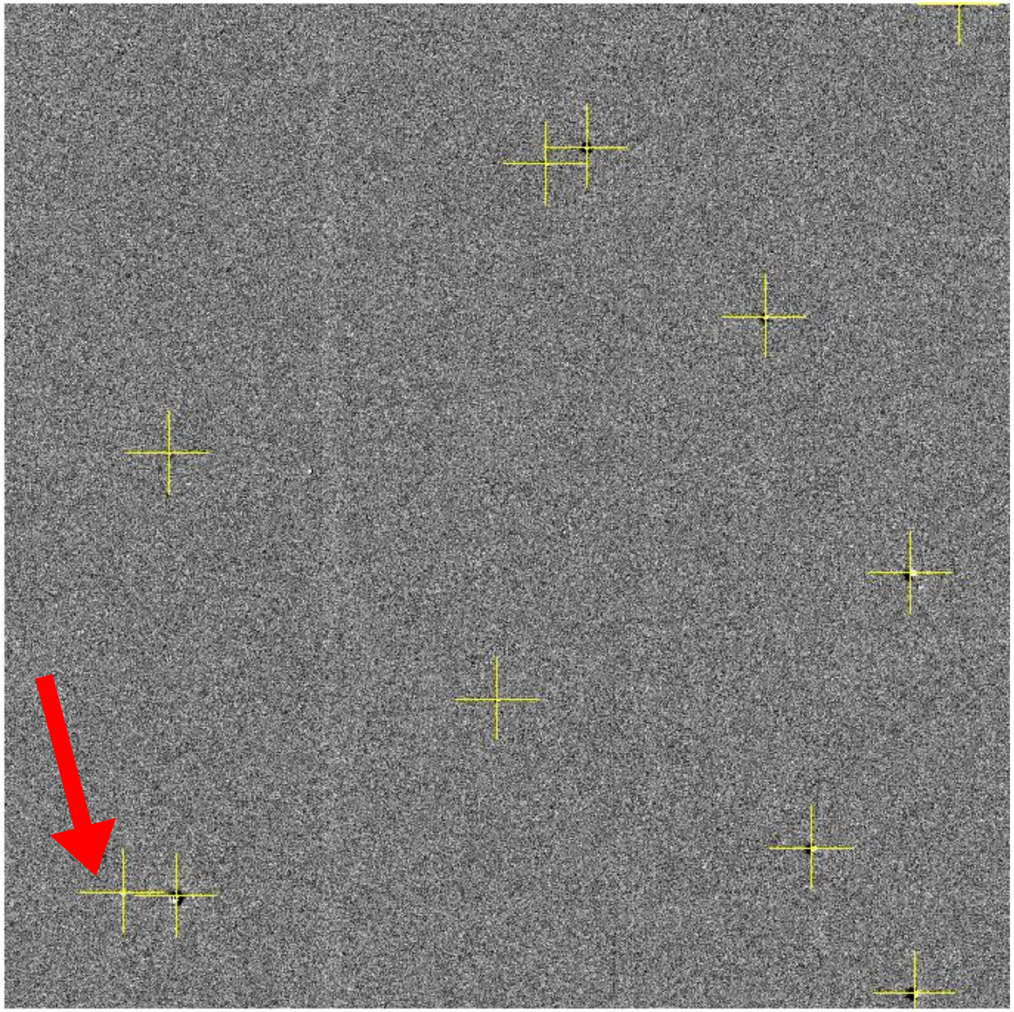
Tests on Image Subtraction



Source detection for the subtracted image (without PSF-matching), using the original DETECTED mask calculated on the processCCD function.

9 false positives detected.

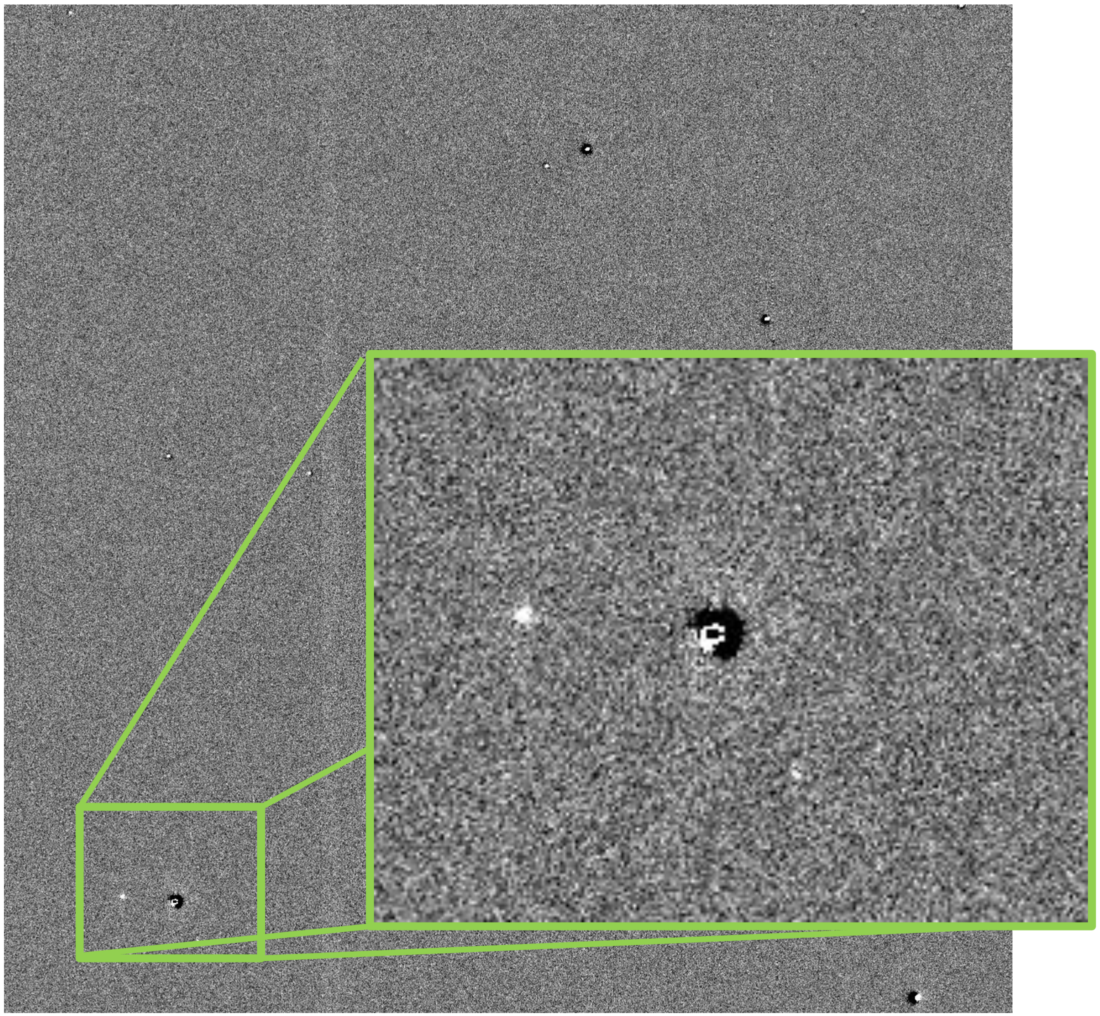
Tests on Image Subtraction



Source detection for the subtracted image (without PSF-matching), using the original DETECTED mask calculated on the processCCD function.

The supernova was detected as well.

Tests on Image Subtraction

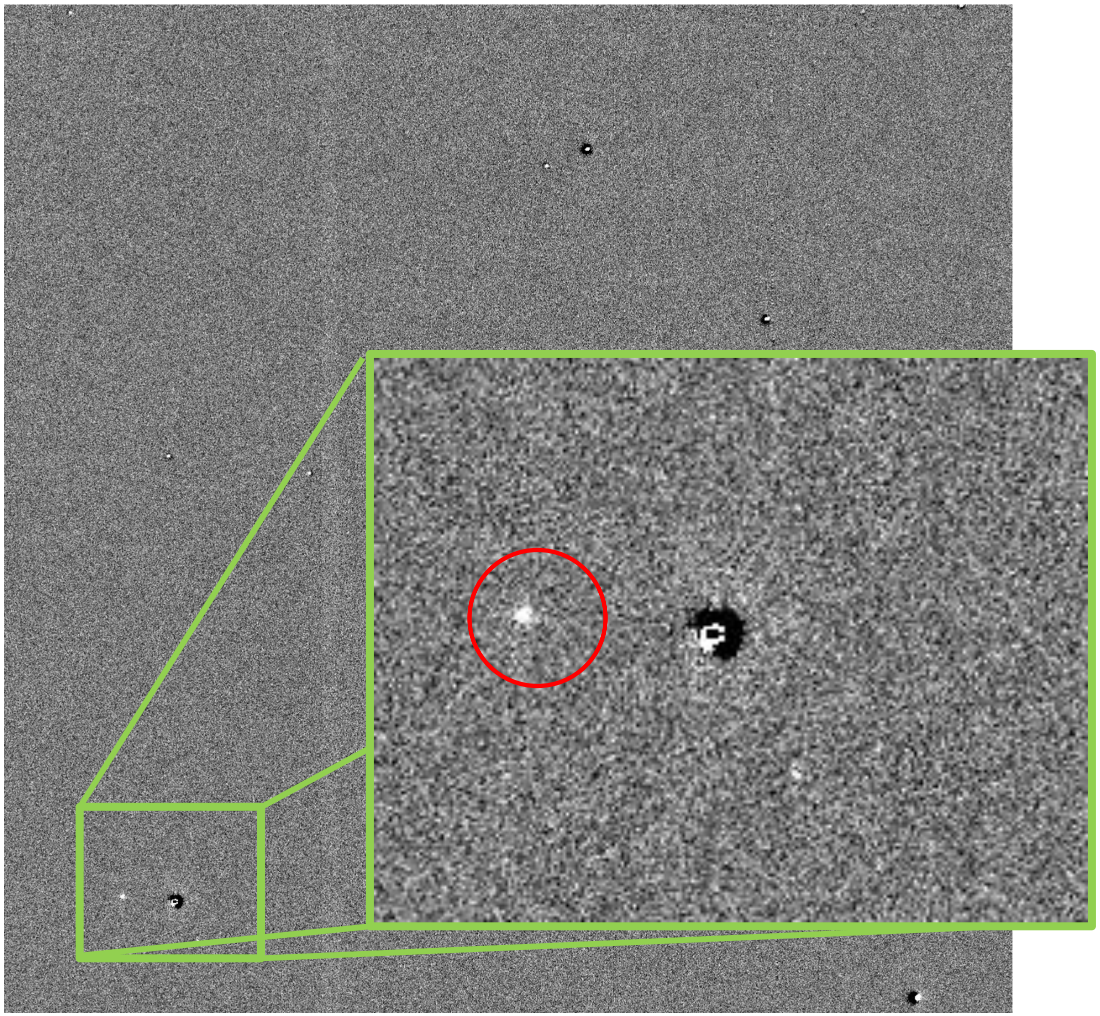


Subtracted Image without using PSF-Match (pixel-wise subtraction).

More problematic PSF residuals are present in this image.

Nevertheless, we can see that the supernova is detected as well…

Tests on Image Subtraction



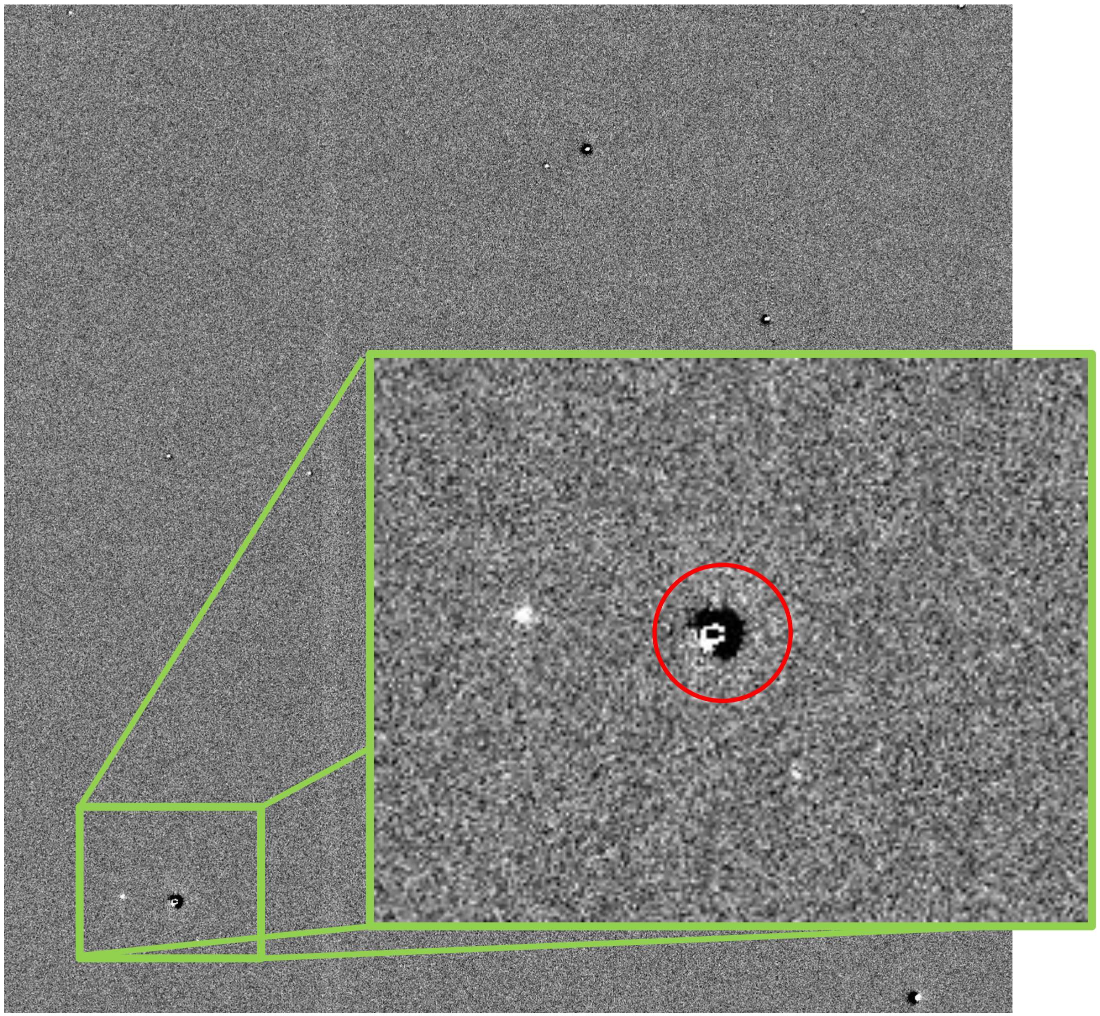
Subtracted Image without using PSF-Match (pixel-wise subtraction).

More problematic PSF residuals are present in this image.

Nevertheless, we can see that the supernova is detected as well…

Supernova detected!

Tests on Image Subtraction



Bad source subtraction!

Subtracted Image without using PSF-Match (pixel-wise subtraction).

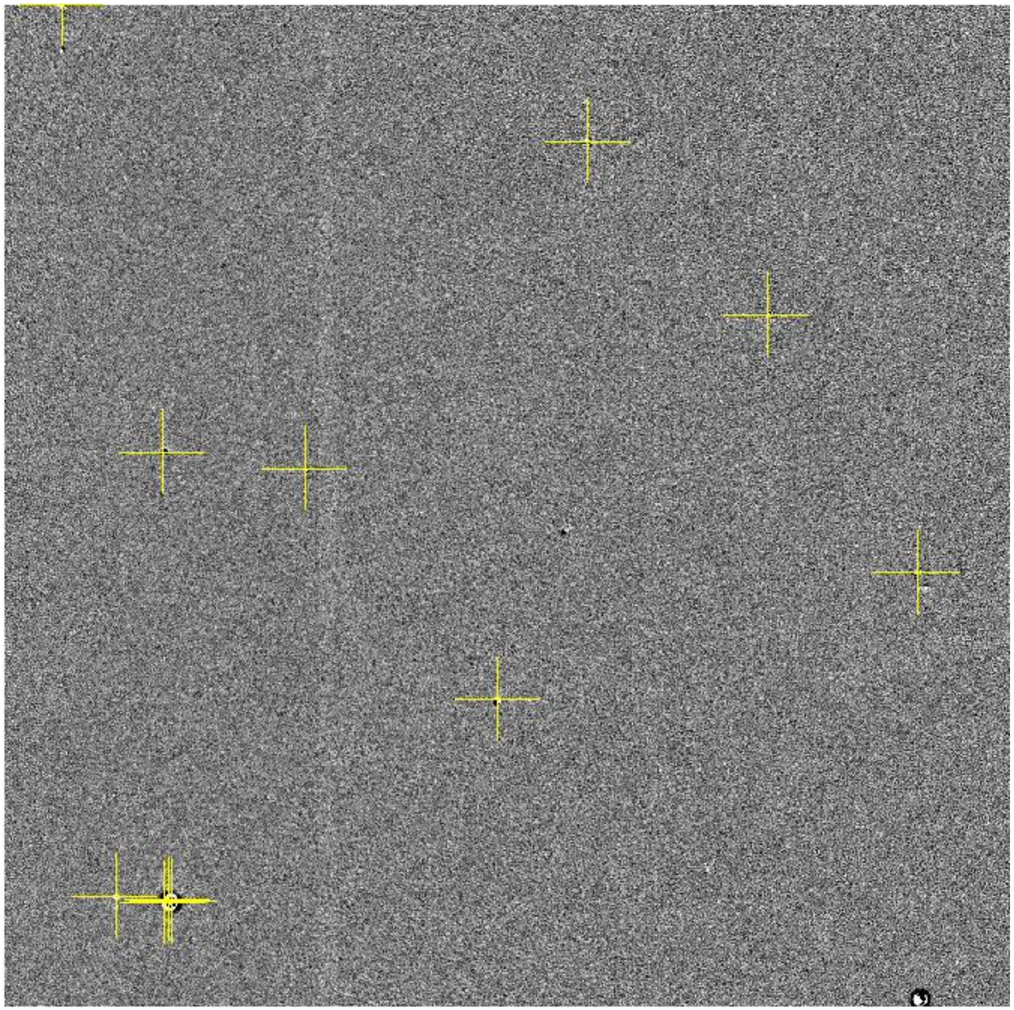
More problematic PSF residuals are present in this image.

Nevertheless, we can see that the supernova is detected as well…

Outline

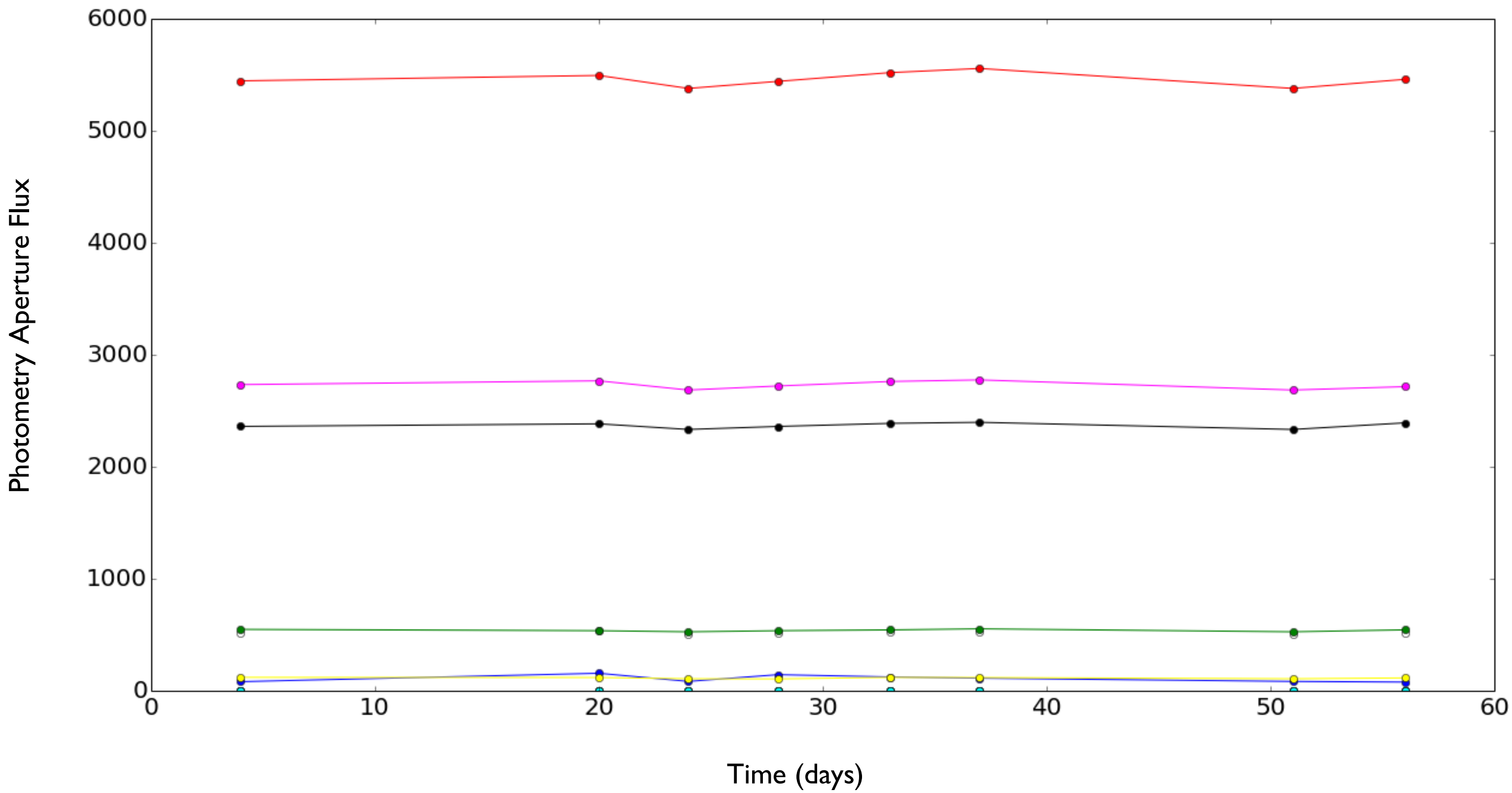
- Methodology
- Image Subtraction with PSF Matching
- Tests on Image Subtraction
- Light Curves
- Image Quality and Artifacts
- Other Tests
- Conclusions
- Challenges

Light Curves



Let's try tracing the curves. Using one visit of the day of the supernova intensity maximum, let's match these sources on the subtraction with the sources on the patch.

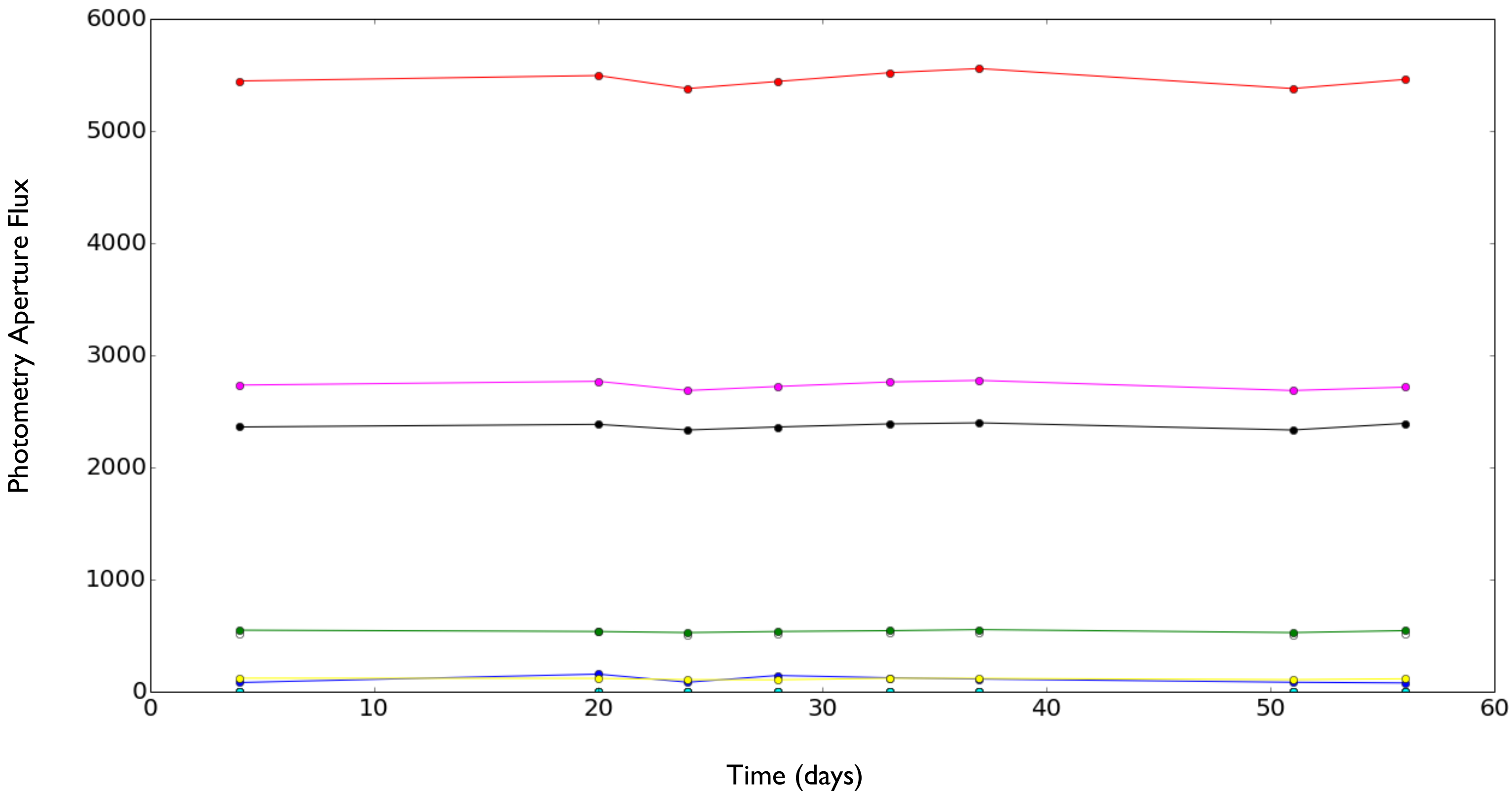
Light Curves



We subtracted and detected the sources for 9 different days:

- 04-05-2006 (day 4)
- 20-05-2006 (day 20)
- 24-05-2006 (day 24)
- 28-05-2006 (day 28)
- 02-06-2006 (day 33)
- 06-06-2006 (day 39)
- 20-06-2006 (day 53)
- 25-06-2006 (day 58)

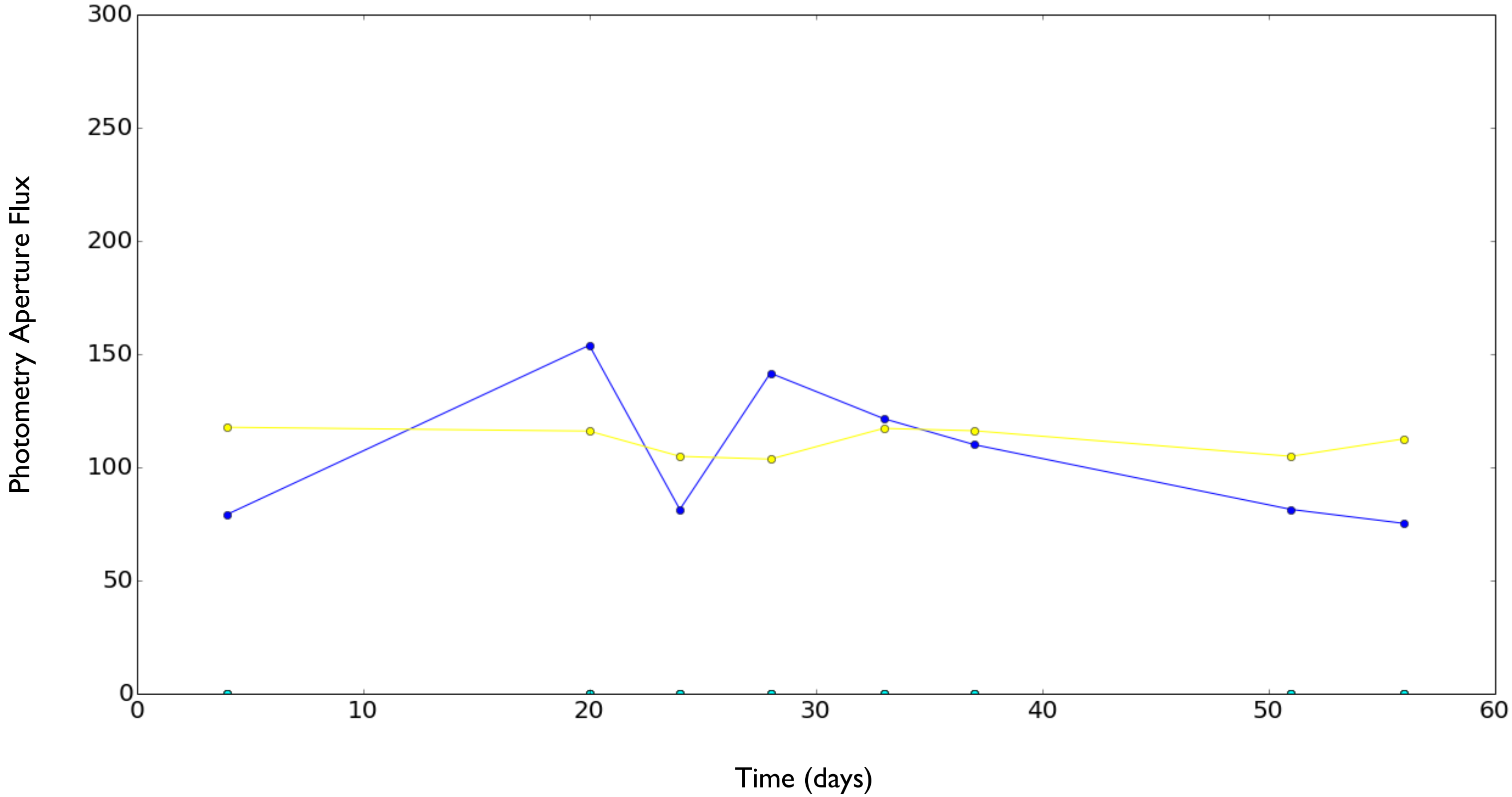
Light Curves



The supernova light curve doesn't pop.

The supernova is the blue line at the bottom of the plot.

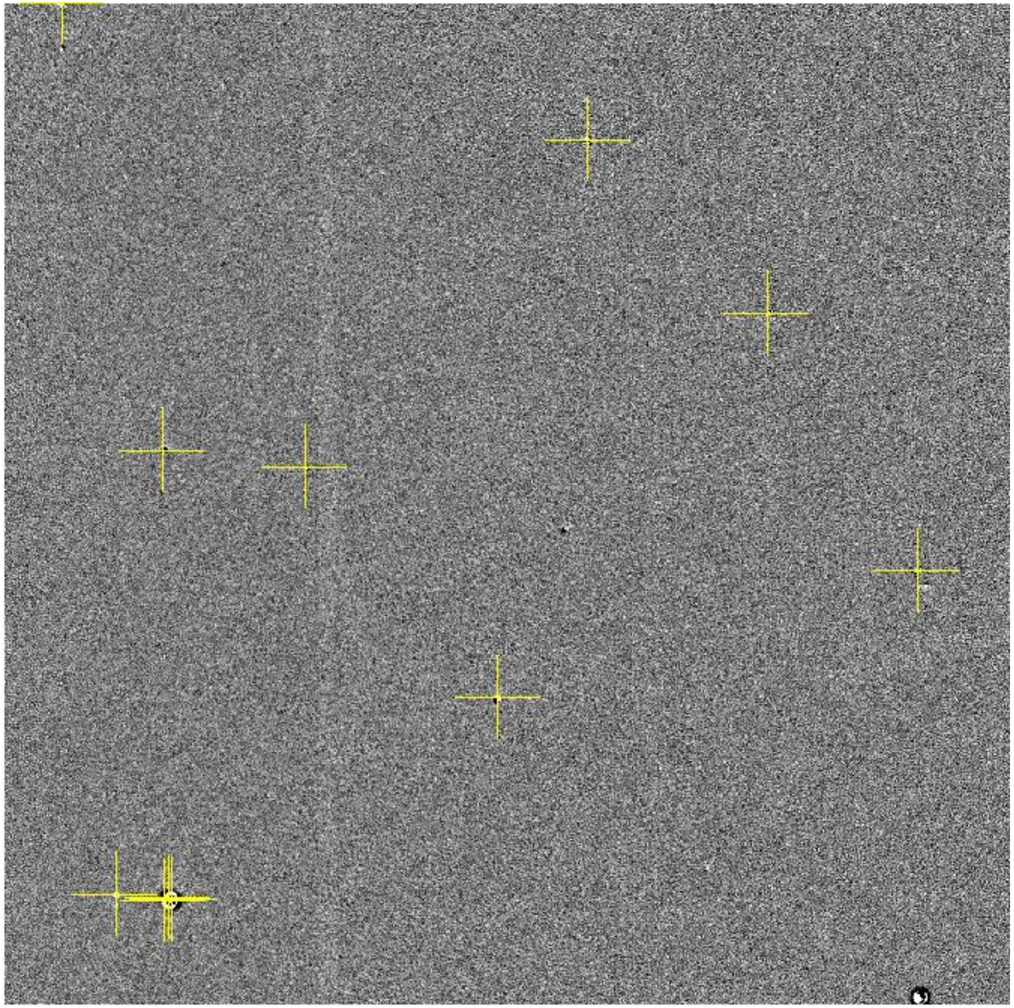
Light Curves



Zooming the plot (and looking at the blue dots).

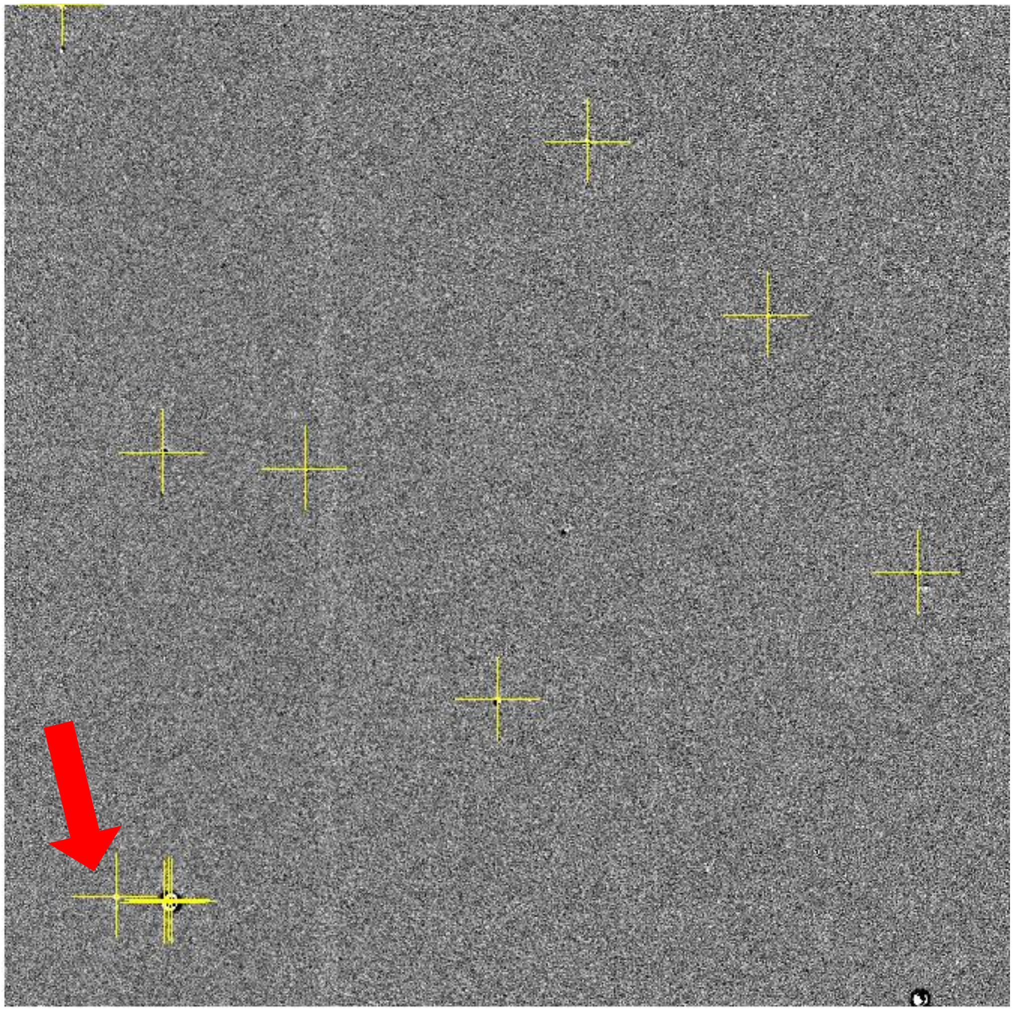
The supernova light curve is still not obviously poping out.

Light Curves



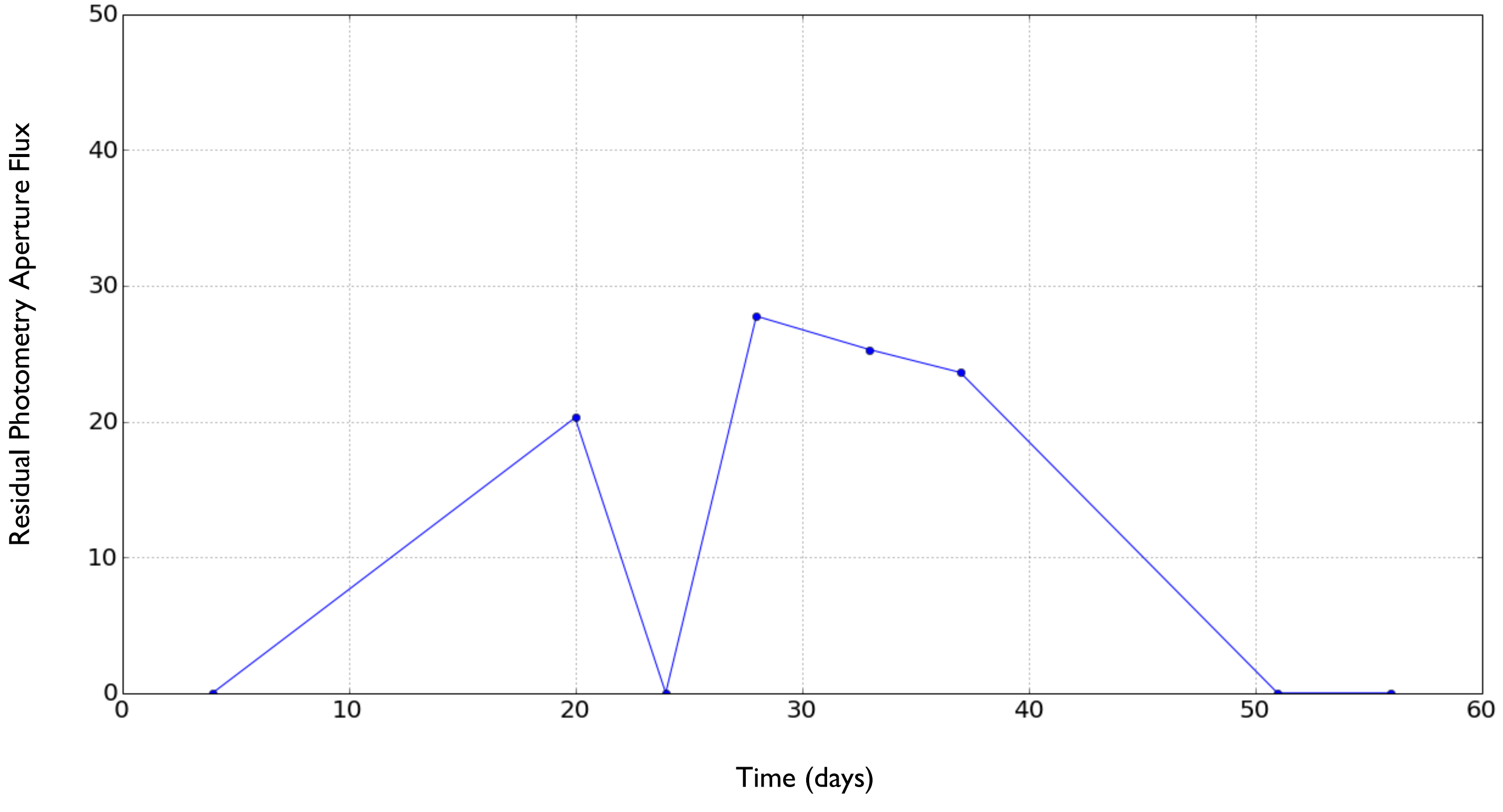
Now, let's try with the light curve on the set of subtracted images…

Light Curves



Now, let's try with the light curve on the set of subtracted images…

Light Curves

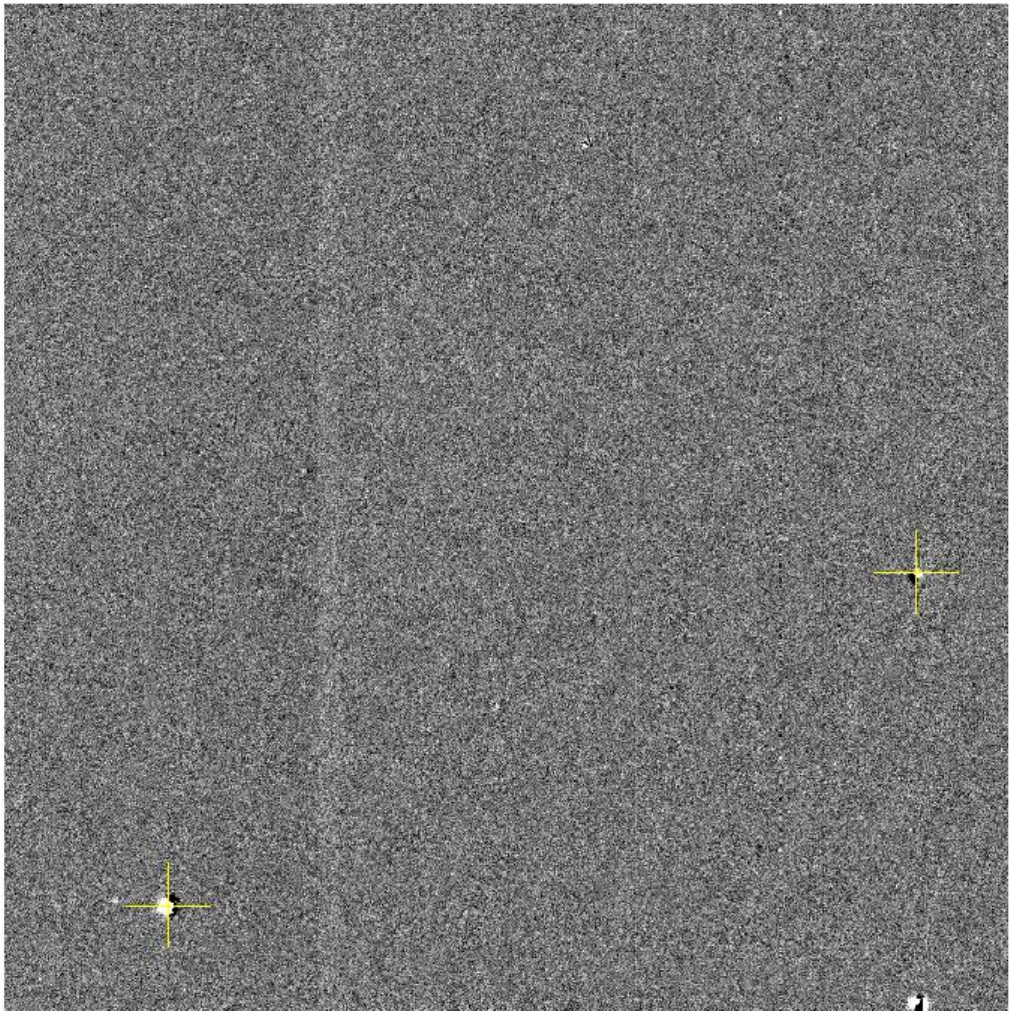


There's one missing value, but the "peak" structure is present.

Outline

- Methodology
- Image Subtraction with PSF Matching
- Tests on Image Subtraction
- Light Curves
- Image Quality and Artifacts
- Other Tests
- Conclusions
- Challenges

Image Quality and Artifacts

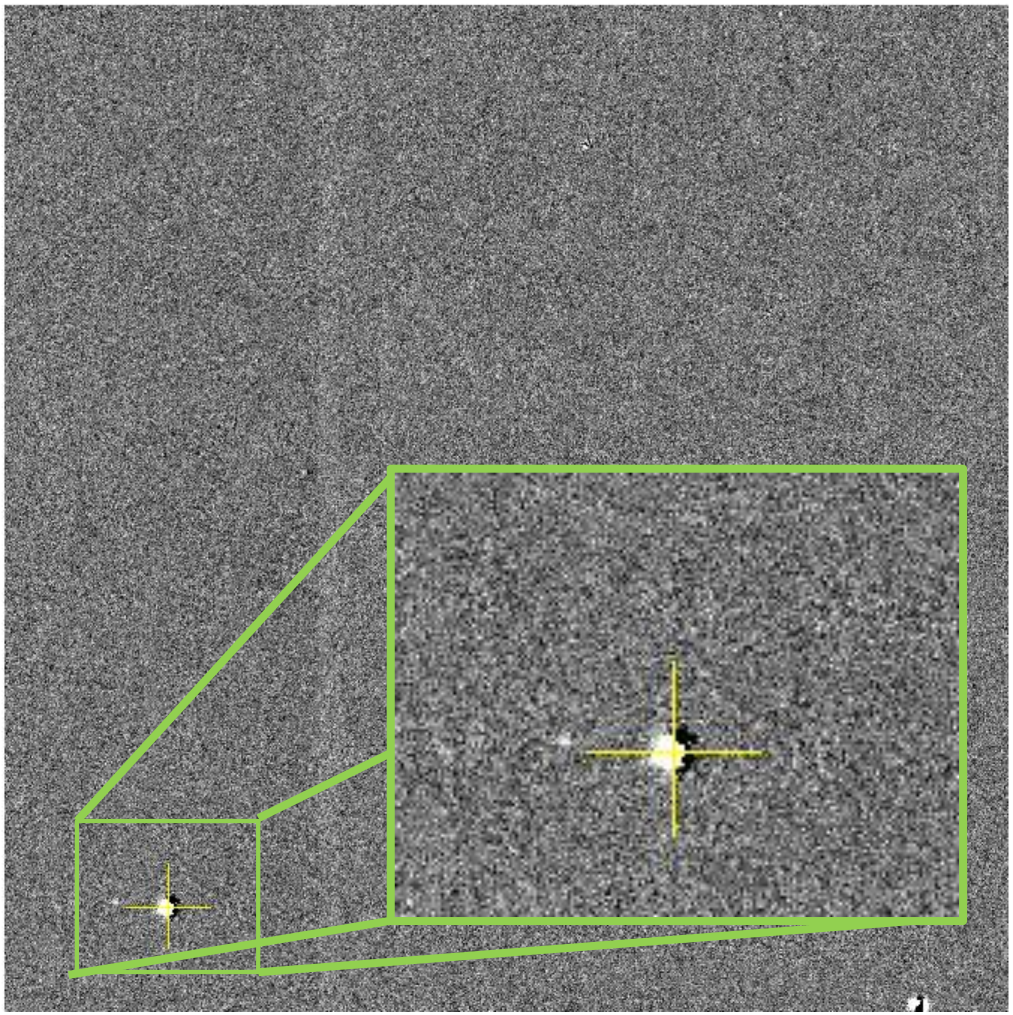


Detections were strongly impacted by the quality of images.

This subtraction corresponds to another visit on a day previous to the supernova peak of intensity.

With a bad image quality and despite using the same threshold that on the other images, the supernova is missed by the algorithm.

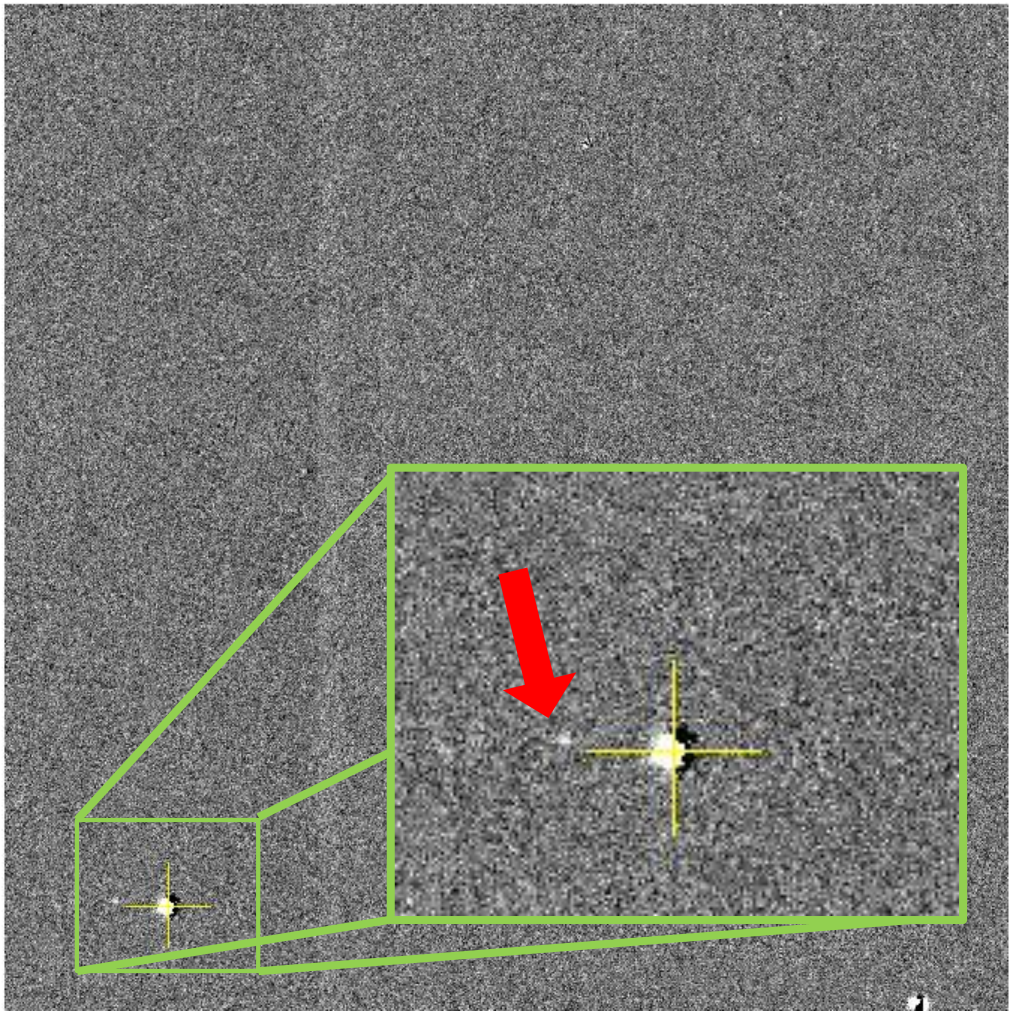
Image Quality and Artifacts



Detections were strongly impacted by the quality of images.

In this subtracted image, the supernova is present, but not detected.

Image Quality and Artifacts



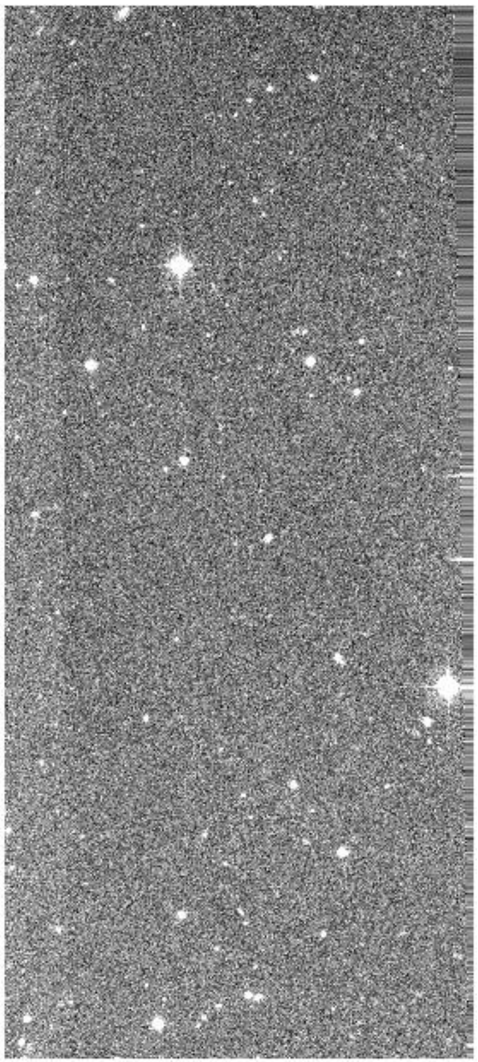
Detections were strongly impacted by the quality of images.

In this subtracted, image, the supernova is present, but not detected.

Outline

- Methodology
- Image Subtraction with PSF Matching
- Tests on Image Subtraction
- Light Curves
- Image Quality and Artifacts
- Other Tests
- Conclusions
- Challenges

Other Tests



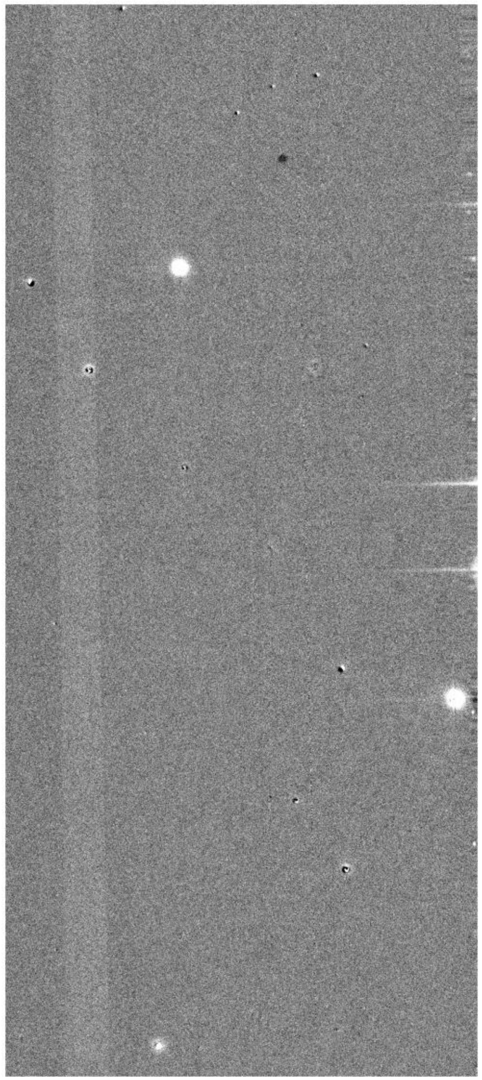
Single visit

Coaddition of 5 visits

Subtraction for patches of different dimensions (trying to remain close to the CCD).

There are more border effects in these images. The quality of the subtraction will be affected.

Other Tests



Subtraction image

Subtraction result:

Still several sources present on the image. Artifacts and border effects are present.

Keep the sizes limited?

How does the patch impact the quality of the subtraction?

Ideal values?

Other Tests

Use of Python astronomical image processing libraries for fast-prototyping, tests and benchmarking, with CFHT and Simulated Images.

https://github.com/mariacamilaremolinagutierrez/MonitoriaInvestigacionLSST/blob/master/Sustraccion.ipynb

https://github.com/sercharpak/Monitoria_Investigacion_LSST_2015-2/blob/master/Detection_Comparation_Sources_Sep_Simulation.ipynb

Outline

- Methodology
- Image Subtraction with PSF Matching
- Tests on Image Subtraction
- Light Curves
- Image Quality and Artifacts
- Other Tests
- Conclusions
- Challenges

CONCLUSIONS

- With a better understanding of the subtraction method, we are now able to obtain images with less defects, and we will be able to compare them with the Late Winter 2013 report.
- Reduction of false-positive detections by asserting the quality of subtractions. Improvements over the input images and discrimination over the result images.
- With the understanding of the algorithm and the implementation as Python notebooks, we are advancing towards some proposals to improve the pipeline on its initial and final stages.

Outline

- Methodology
- Image Subtraction with PSF Matching
- Tests on Image Subtraction
- Light Curves
- Image Quality and Artifacts
- Other Tests
- Conclusions
- Challenges

CHALLENGES

- Measure how the patch dimensions affect the false positive rate (should we modify and adjust the parameters of the PSF-matching method?).
- Consider the false negative detections and their relation with the input image quality.
- Find an adequate methodology to test improvements quickly, without sacrificing accuracy.
- Refine the fast-prototyping proposal for theoric ideas.