SNIa detection and classification in the SNLS deferred photometric analysis

Anais Möller

partially based on
JCAP 2015.04 (2015) p. 041. 2015
arXiv:1501.02110

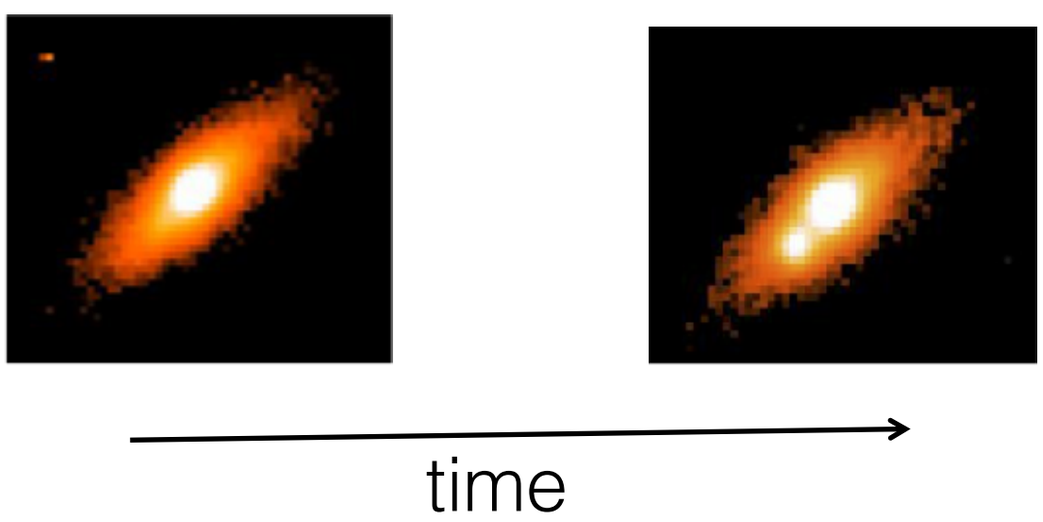
A. Möller, V. Ruhlmann-Kleider, F. Lanusse,J. Neveu ,N. Palanque-Delabrouille and J.-L. Starck

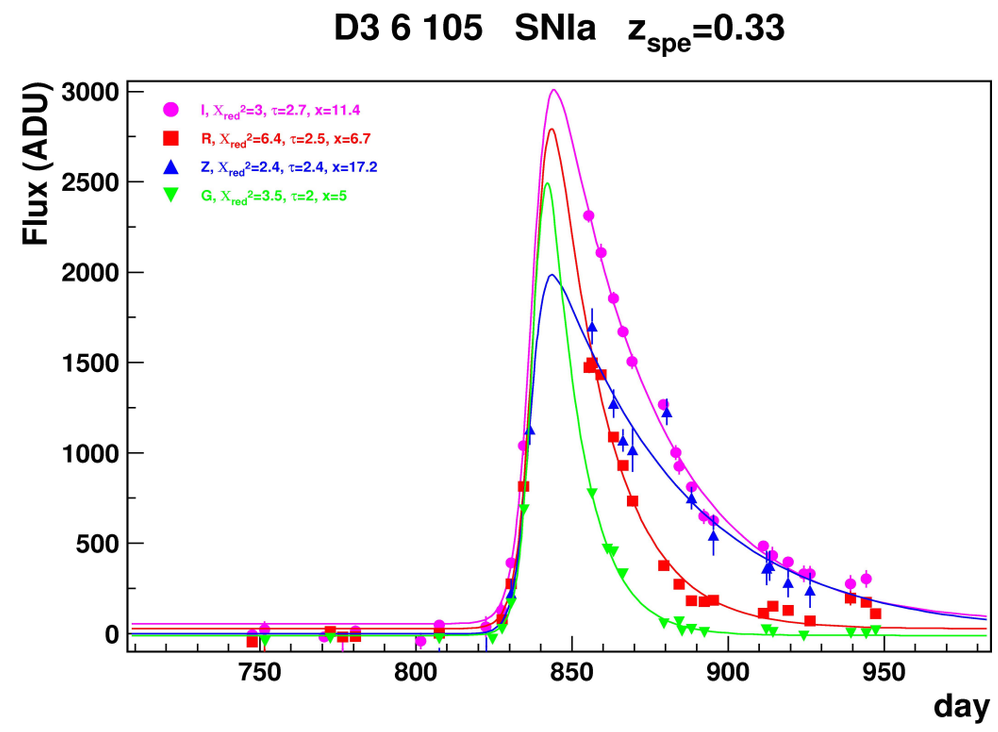
Rencontres du Vietnam 2015

Overview

- SNe Ia
  - good distance indicators: standard candles
  - 1998 discovery of **accelerated expansion**

=> Dark Energy





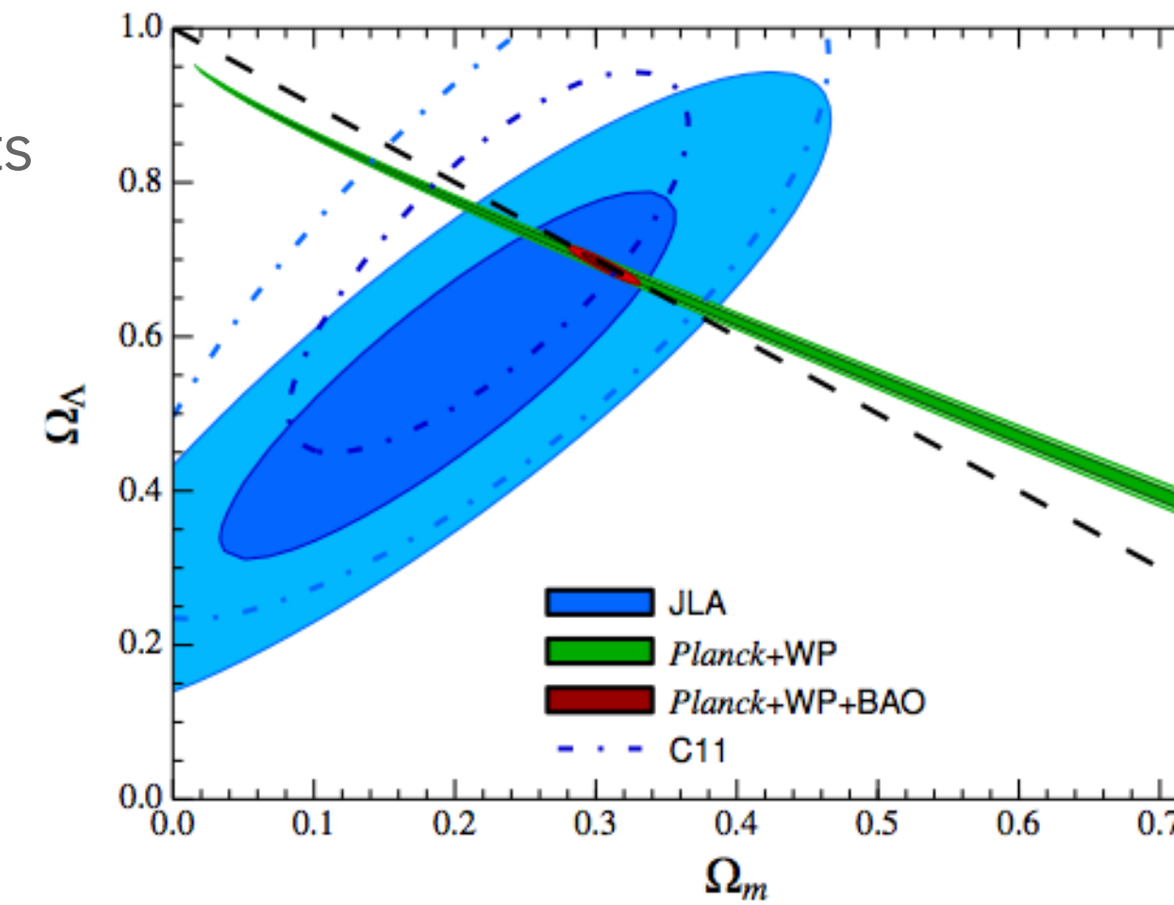
Overview

Almost 20 years later still **many unanswered questions…**

- take advantage of different measurements
  CMB, BAO

- challenges in the **SNe Ia** field
  - <u>more measurements</u>
  - **more precise** measurements

  to be faced by SNLS, DES, LSST.



Betoule et al. 2014

JLA + CMB+ BAO w =−1.027 ± 0.055

(using Planck 2013)

this presentation:

the improvements on the <u>SNLS deferred photometric pipeline</u>

SNLS

Goal: Determining the equation of state of dark energy with high precision (5% on w)

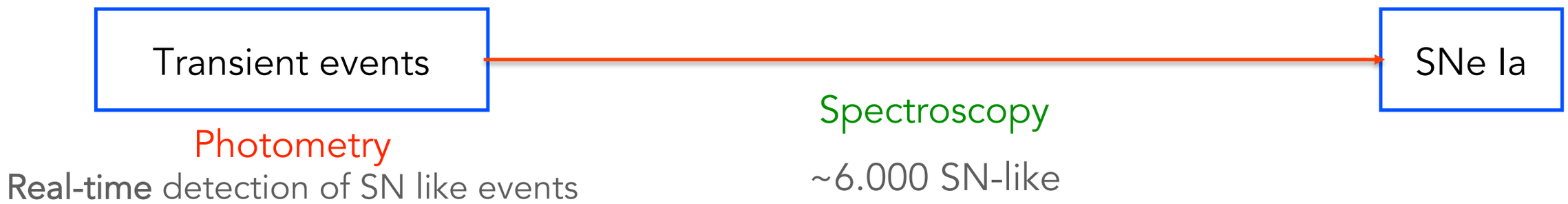
- Canada-France-Hawaii Telescope in Hawaii
- **MegaCam** : 36 CCD mosaic
- 4 broadband filters
- 4 fields of 1 square degree

- Redshift: $0.2 < z < 1$

- Observations: 2003-2008
  - **SNLS3**: first three years *(public data)*
  - **SNLS5**: all years *(currently being processed)*

Standard vs. photometric analysis

Standard SNLS approach: e.g. *Astier et al. 2005*



but spectroscopic resources are limited!

SNIa detection and classification in the **SNLS deferred photometric** analysis

- **no spectroscopy** required
- **differed** detection of all kinds of transient events
- **larger number** of detections
- **larger redshift** coverage
- sensible to **other SN types**

Standard vs. **photometric** analysis

Standard SNLS approach

Transient events → SNe Ia

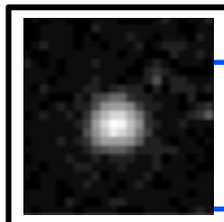
Photometry

Real-time detection of SN like events

Spectroscopy

~6.000 SN-like

Saclay SNLS group: photometric approach



Transient events → SN-like candidates

photometry

Photometry

1483 candidates

SN-like candidates → SNe Ia

SN-like candidates → SN CC

photometry

Transient detection

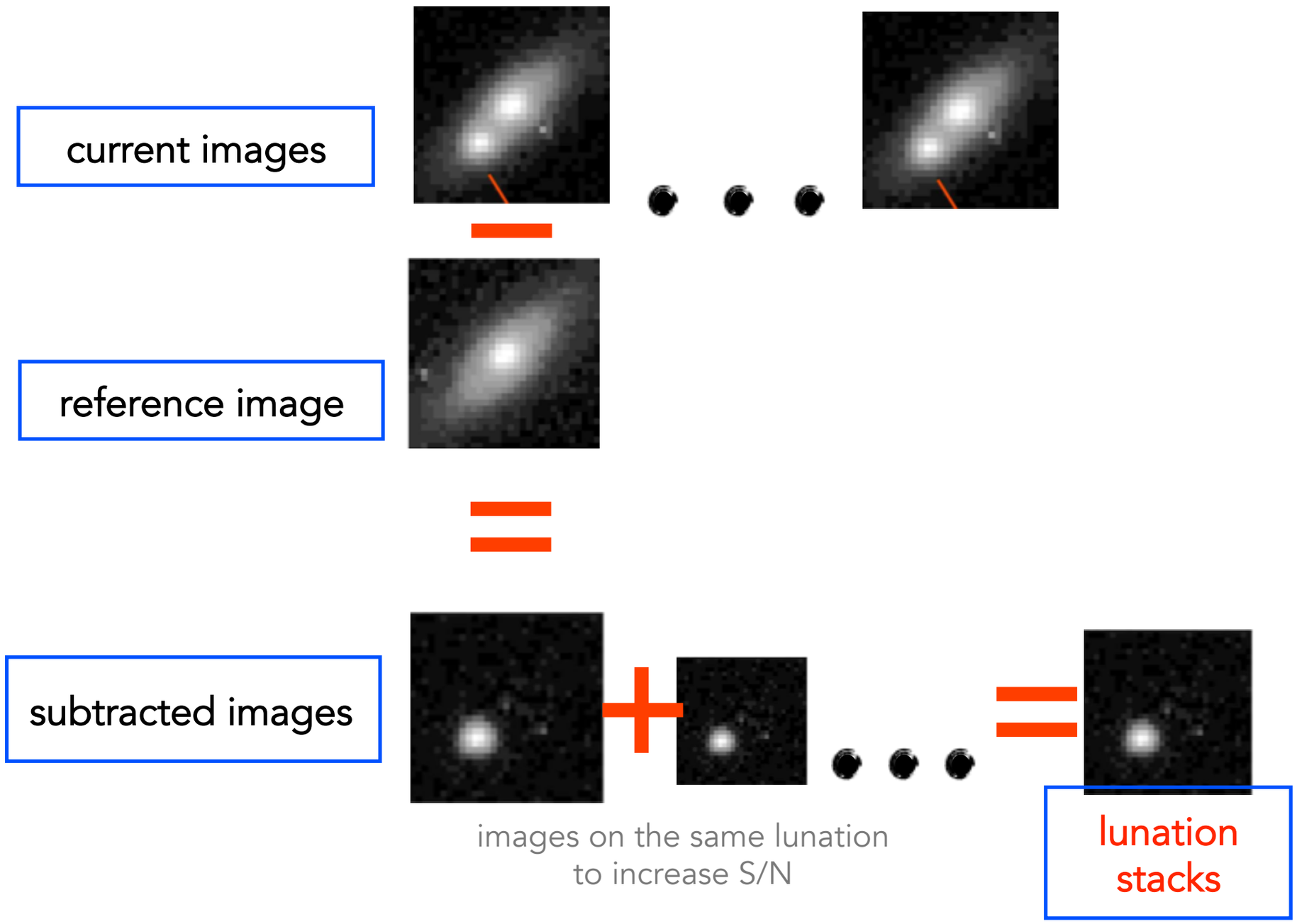
SN Classification

G. Bazin et al. A&A 534, A43 (2011) Photometric selection of Type Ia supernovae in the Supernova Legacy Survey.

G.Bazin et al. A&A 499, Issue 3,(2009) The core-collapse rate from the Supernova Legacy Survey.

Transient **detection**

Subtraction of reference images from "current"

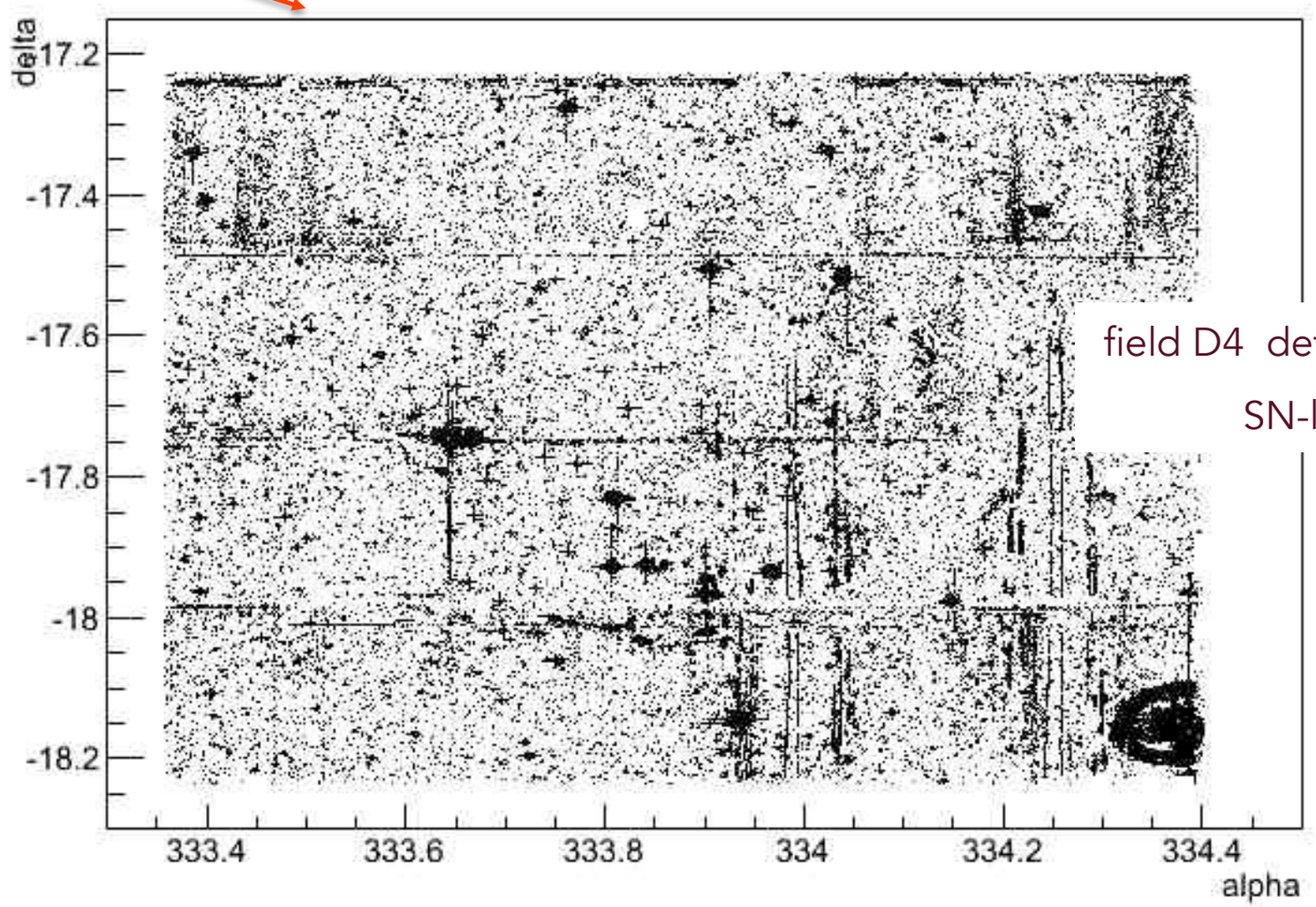


Transient **detection map**

lunation stacks

SNLS3, 4 fields
Detections: **302,987**
SN-like candidates: **1,483**

SN-like candidates
+ spurious detections



field D4 detections 90,971

SN-like 362

I. Improving **detection** of **transient** events

goal:

reducing number of spurious detections
while maintaining number of SN-like events

a. reduce artefacts: MCA
b. detect events
c. MC and data studies

JCAP 2015.04 (2015) p. 041. 2015
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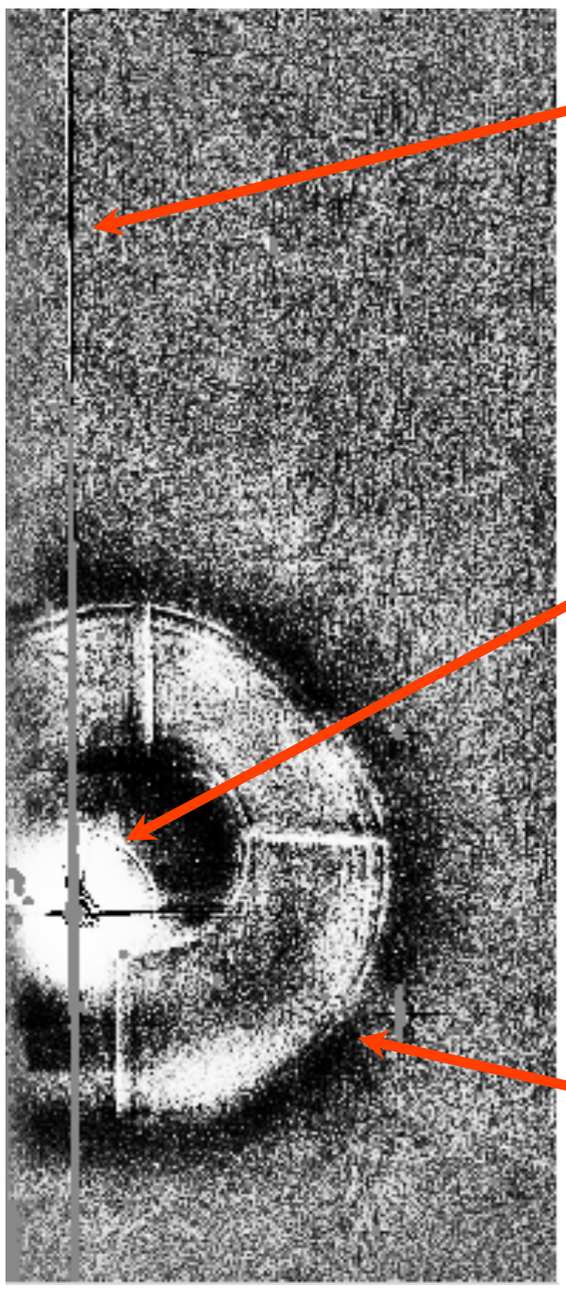
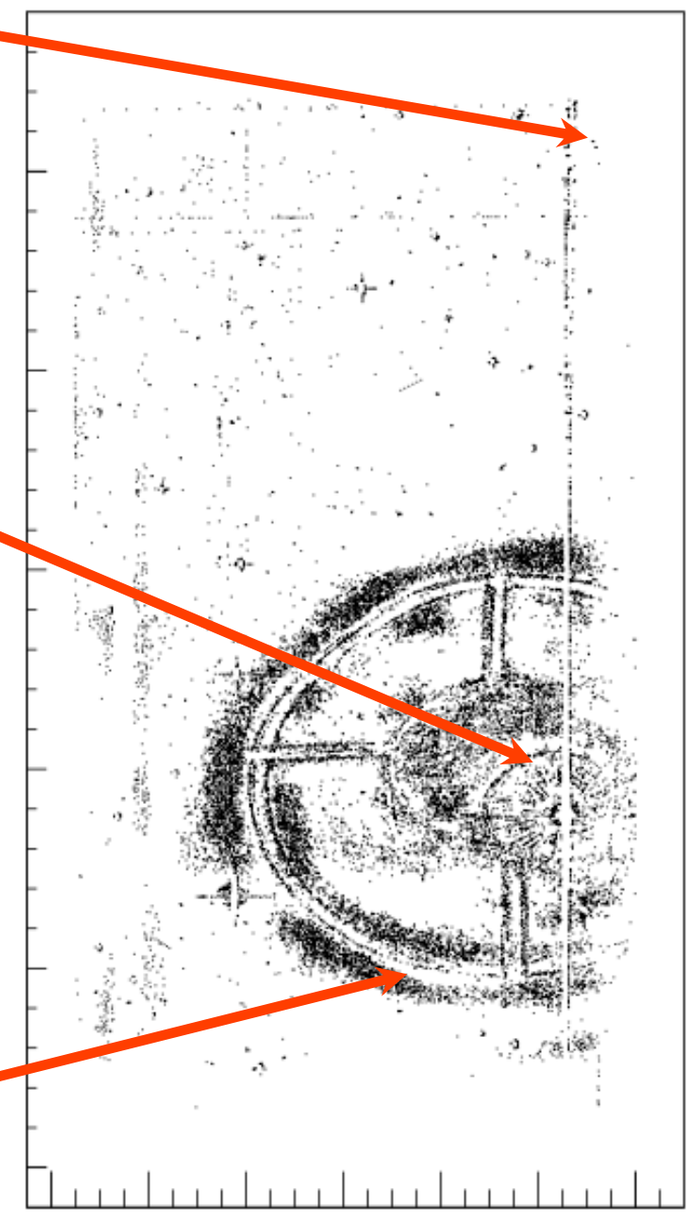
Artifacts that yield spurious detections

stack example

detection map

resampling and mask

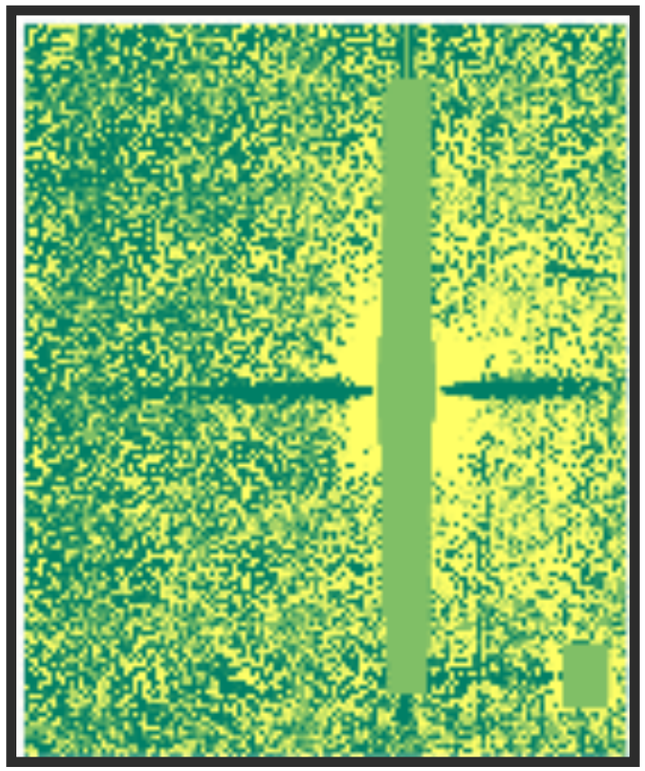




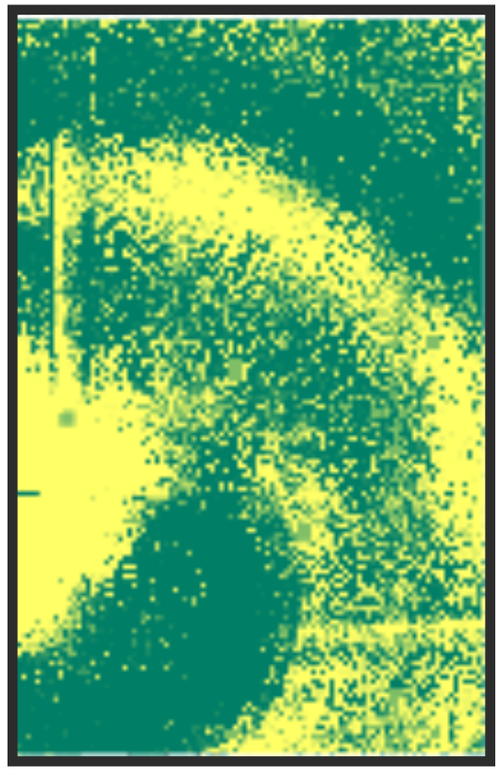
saturated star

mounting

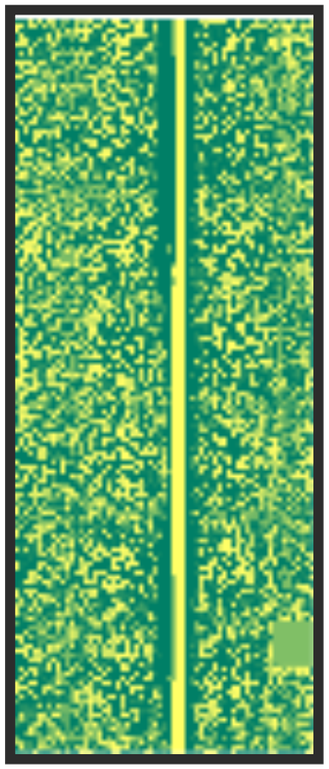
Common defects-artifacts



Bright star, mask

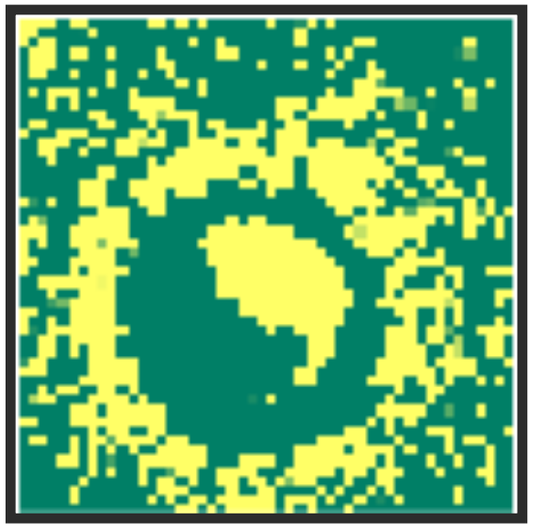


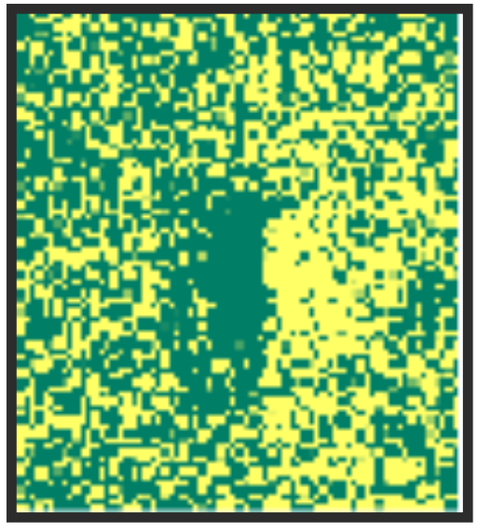
Mounting shadow



Resampling

"Large" scale





Dipoles

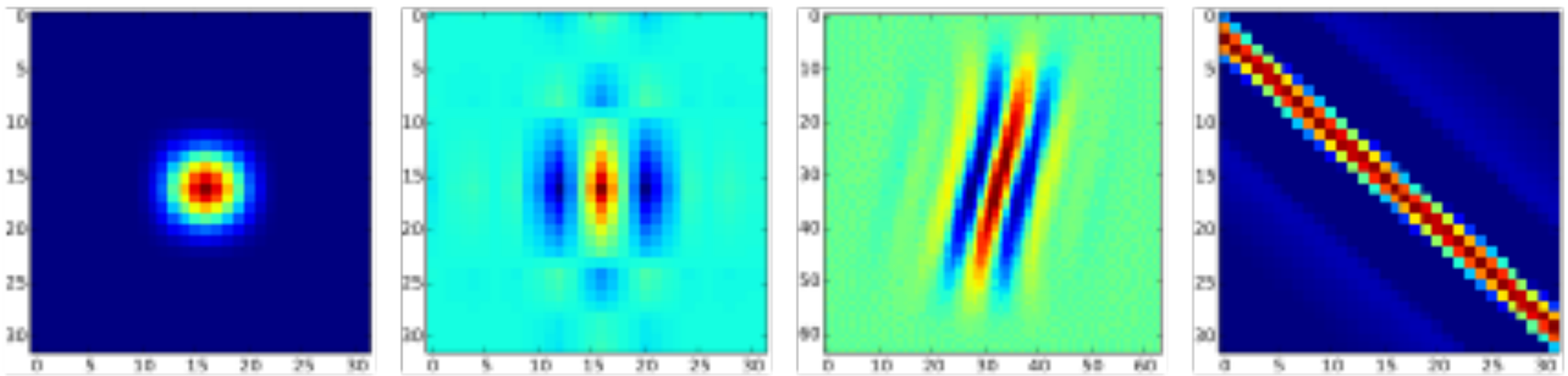
"Small" scale

Morphological Component Analysis

*in collaboration with **F. Lanusse** and **J-L. Starck** from SAp, CEA*

Hypothesis: a stack image can be decomposed completely in different “dictionaries”

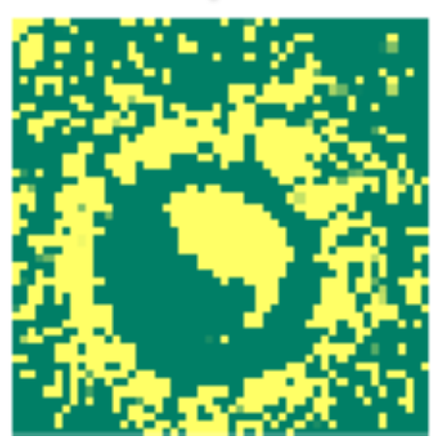
dictionaries



(A) Starlet (B) Bi-orthogonal (C) Curvelet (D) Ridgelet

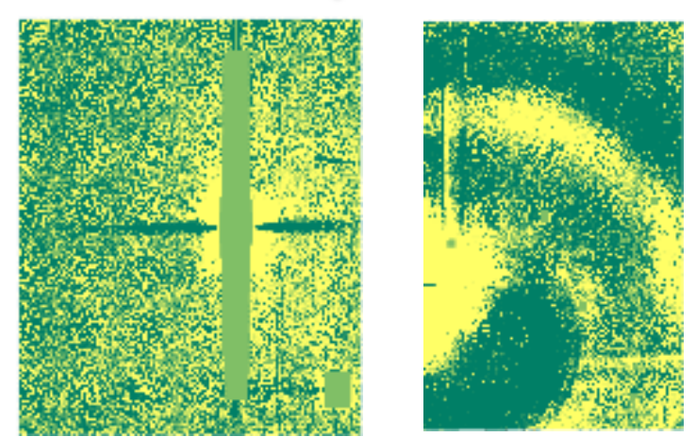
objects

Ia



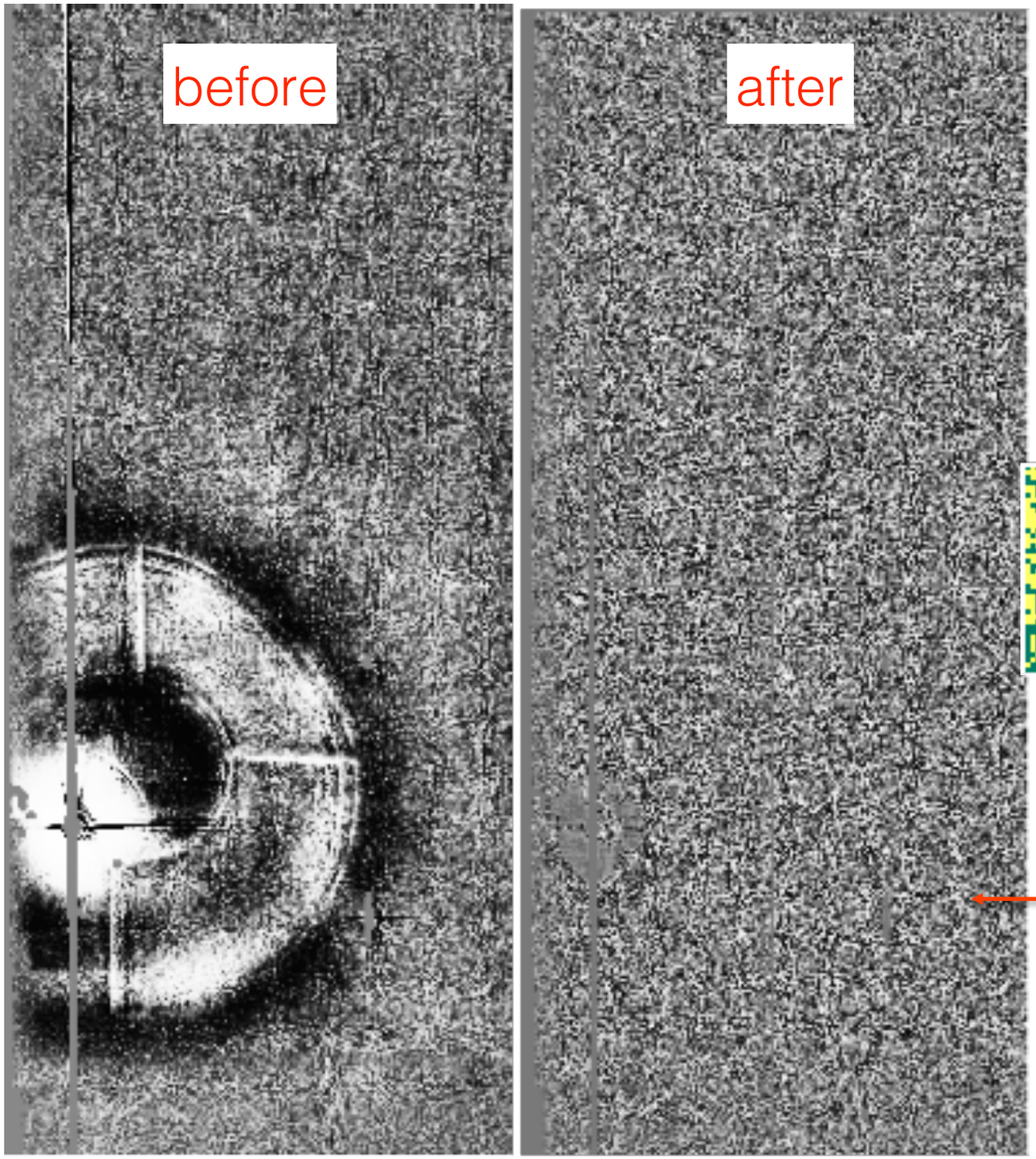
dipole

defects



saturated star, mounting,…

Step 1: removal main artifacts

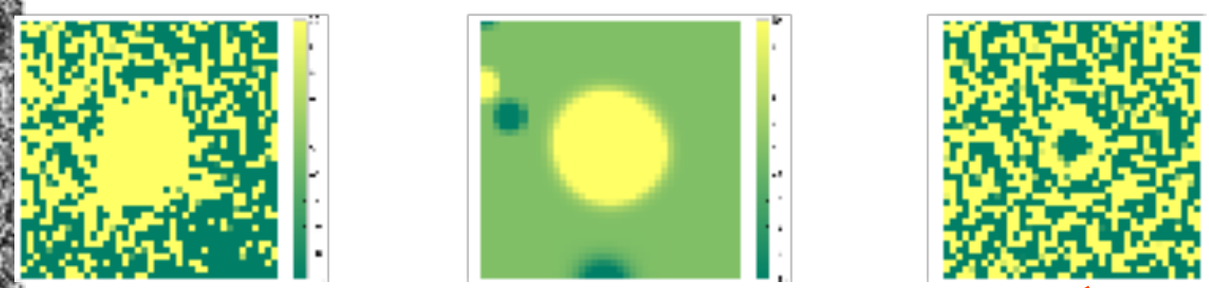


Algorithm by *Starck et. al*

-Starlet, wavelet, ridgelet, curvelet dictionaries

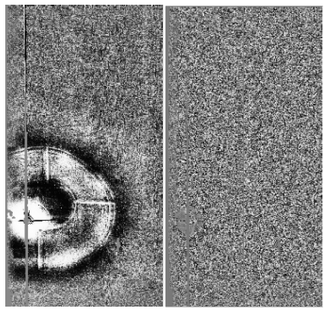
-Iterative

- Noise assumed stationary and gaussian



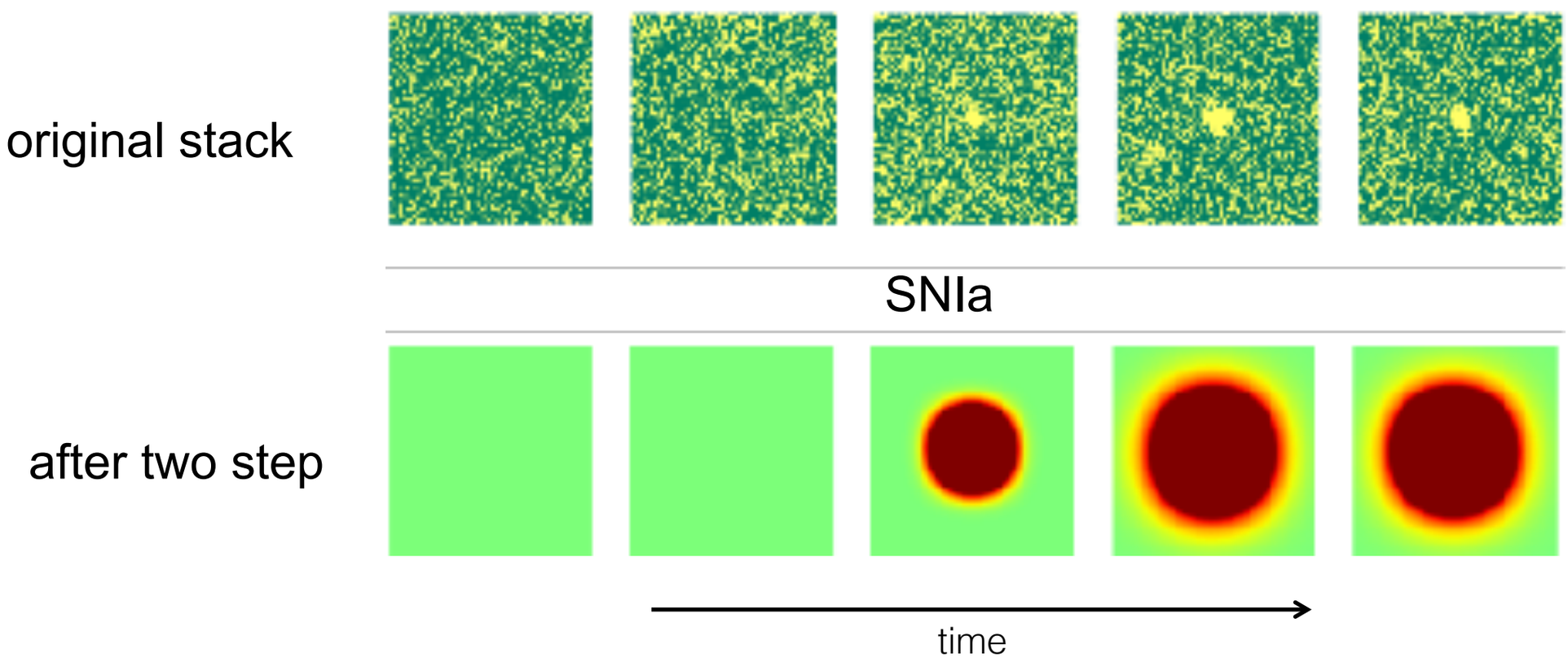
Starlet + residuals

Step 2: non-stationary noise

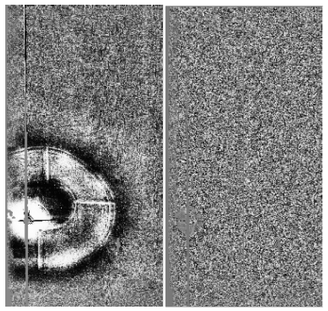


- Step 1: removal of main artifacts

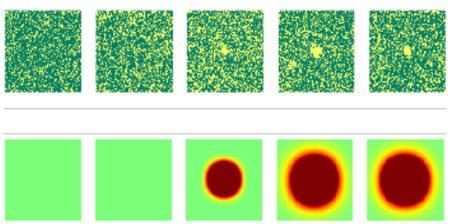
- Step 2: extract events taking into account non-stationary noise



Detection strategy



- Step 1: removal of main artifacts



- Step 2: extract events taking into account non-stationary noise

- New detection strategy:

1. extract events from an image: *validating* detection
2. reconstruct coordinates: assign coordinates

We addressed:

- pileup due to several years of data!
- coordinate resolution affect magnitude bias

Results

Monte Carlo artificial images in the i filter for one year survey.

	Old procedure		New procedure			
			No season stacks		With season stacks	
Stack	coordinate resolution ±0.002	magnitude bias ±0.0002	coordinate resolution ±0.002	magnitude bias ±0.0002	coordinate resolution ±0.002	magnitude bias ±0.0002
1-year	0.709	0.0334	0.698	0.0324	0.698	0.0324
3-year	0.725	0.0349	0.715	0.0340	0.710	0.0335
5-year	0.741	0.0365	0.731	0.0355	0.726	0.0350

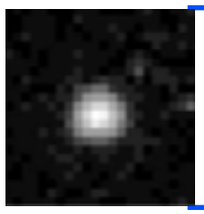
$$m_{bias} = \frac{d^2_{RMS}}{4\sigma_{seeing}}$$

SNLS3 data: Number of **detections** was **reduced** by **more than a factor two**.

	Old procedure		New procedure	
Field	# detected	# SN-like	# detected	# SN-like
All	302,987	1,483	127,808	1,345

AM et al. arXiv:1501.02110

photometric analysis



Transient events

photometry

SN-like candidates

photometry

SNe Ia

SN CC

Transient detection

SN-like

SN Classification

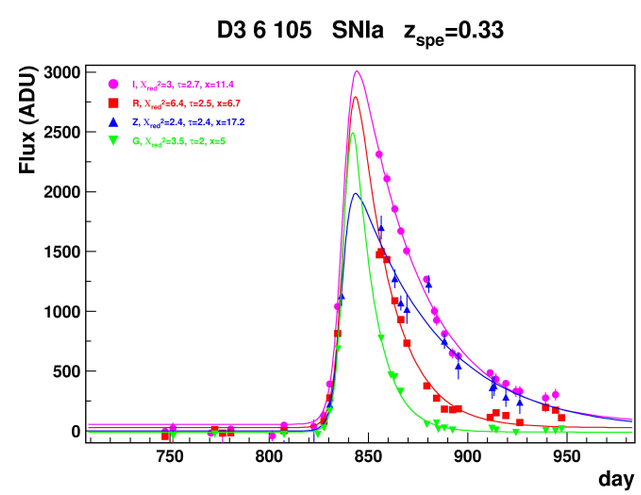
Light curves for all detections are constructed.

Preselection cuts (**SN-like**):

-One significant flux variation SN-like variation

Star rejection

-Quality cuts on light curves



improved

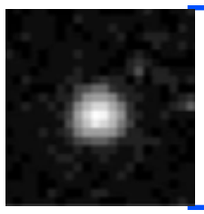
II. **New classification** of supernovae using photometric redshifts:

1. from host galaxy
2. from SNe light curves

take advantage of machine learning techniques

preliminary results

photometric analysis



Transient events → photometry → SN-like candidates → photometry →

SNe Ia

SN CC

Transient detection

✓

improved

SN-like

✓

SN Classification

extract features

(i) light curve fitter

a. SALT2 *Guy et al. 2007*

b. SN general

(ii) redshift

classify

photometric classification

(ii) photometric redshift

a. host-galaxy: coordinates matched to a host galaxy using an external catalogue. *Ilbert et al. 2006*

~3% resolution , catastrophic assignment 0.4%

83% assignment efficiency

b. SN: algorithm by *Palanque-Delabrouille, 2010*

Light curves are fitted using SALT2 using different z hypotheses (best chi squared).

~2% resolution , catastrophic assignment 1.4%

advantage: all SNe have a redshift assignment

SN photometric classification

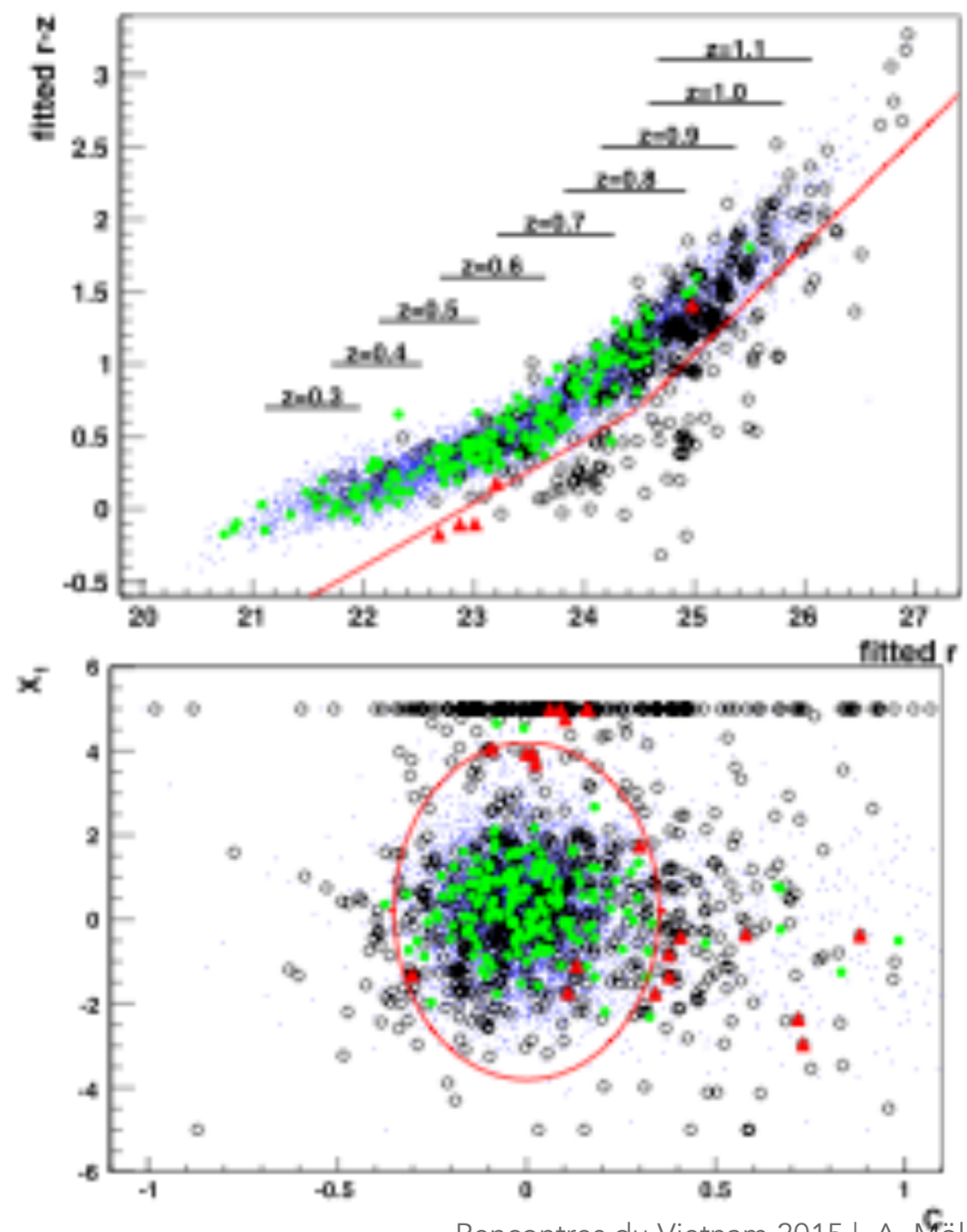
Host-galaxy redshift + SALT2 + seq cuts:

1. Sampling and quality cuts on data
2. Sequential cuts

SNLS3 data
selected events = 485
spectroscopic Ia = 175
spectroscopic CC = 1*

<4% contamination

G. Bazin et. al 2011



SN photometric classification

NEW!

~~Host galaxy~~ redshift + SALT2 + seq cuts

SN redshift + SALT2 + seq cuts:

1. Sampling and quality cuts on data
2. Sequential cuts

SNLS3 data

selected events = 676

spectroscopic Ia = 189

spectroscopic CC = 6

spe and photo CC =13

SN photometric classification

NEW!

SN redshift + SALT2 + ~~seq cuts~~

SN redshift + fit + BDT :

- training of algorithm (using simulations)

  signal: SNIa with good z

  background: Ibc, IIp, Ia with bad z

- classification of data

SN z + fitter variables → BDT response

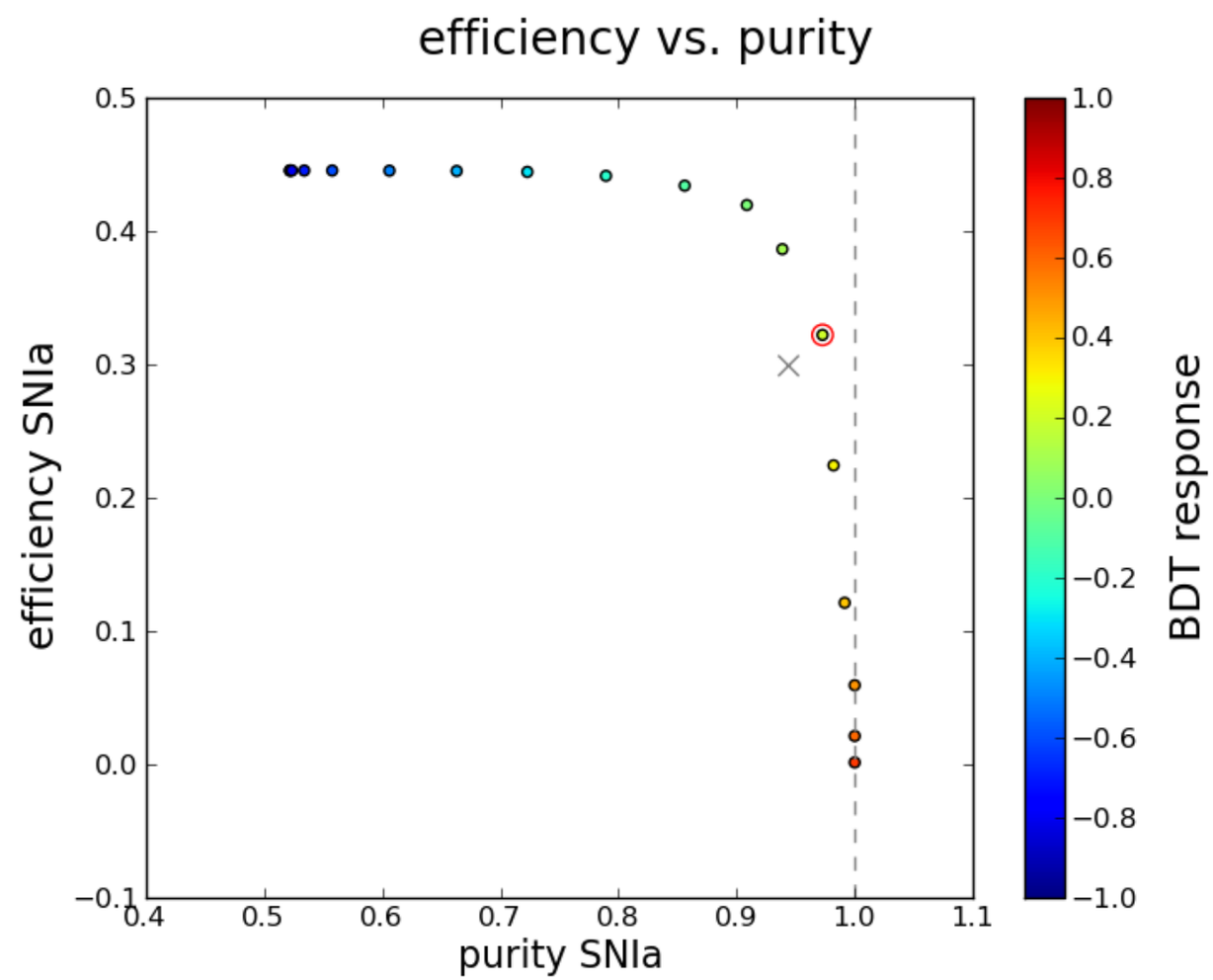
N-dimensional → 1-dimensional

SN photometric classification

preliminary results

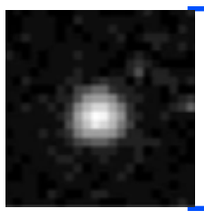
SN redshift + general fit + BDT :

SNLS3 data
selected events = 482
spectroscopic Ia = 187
spectroscopic CC = 1
photometric CC=1



purity SNe Ia	contamination bad redshift SNe Ia	contamination core-collapse	efficiency SNIa
95.82 ± 0.08%	0.29 ± 0.01%	3.88 ± 0.08%	32.2 ± 0.8%

photometric analysis



Transient events → photometry → SN-like candidates → photometry → SNe Ia / SN CC

Transient detection

✓

improved

SN-like

✓

SN Classification

✓

new SN z

Summary

IMPROVEMENT on DETECTION of TRANSIENT events

- **Reduction of spurious** detections of more of a factor of 2.
- New detection strategy provides **better coordinate resolution** and handles better several years **pileup**.

arXiv:1501.02110 and 2015.04 (2015) p. 041. 2015
http://www.cosmostat.org/research/statistical-methods/mca/snls/

CLASSIFICATION of SN types

- Implementation of **SN photometric redshift** analysis.
- Classification using BDT with **contamination < 5%**.

publication in preparation

100% photometric SNe Ia sample.

Stay tuned!

near future: to be applied with SNLS5 data

Backup

Photometric **detection**

Transient events:

Differentiate them from permanent objects

Preprocessing

Elixir Preprocessing:
-Flat-fielding
-Fringe subtraction

Subtraction

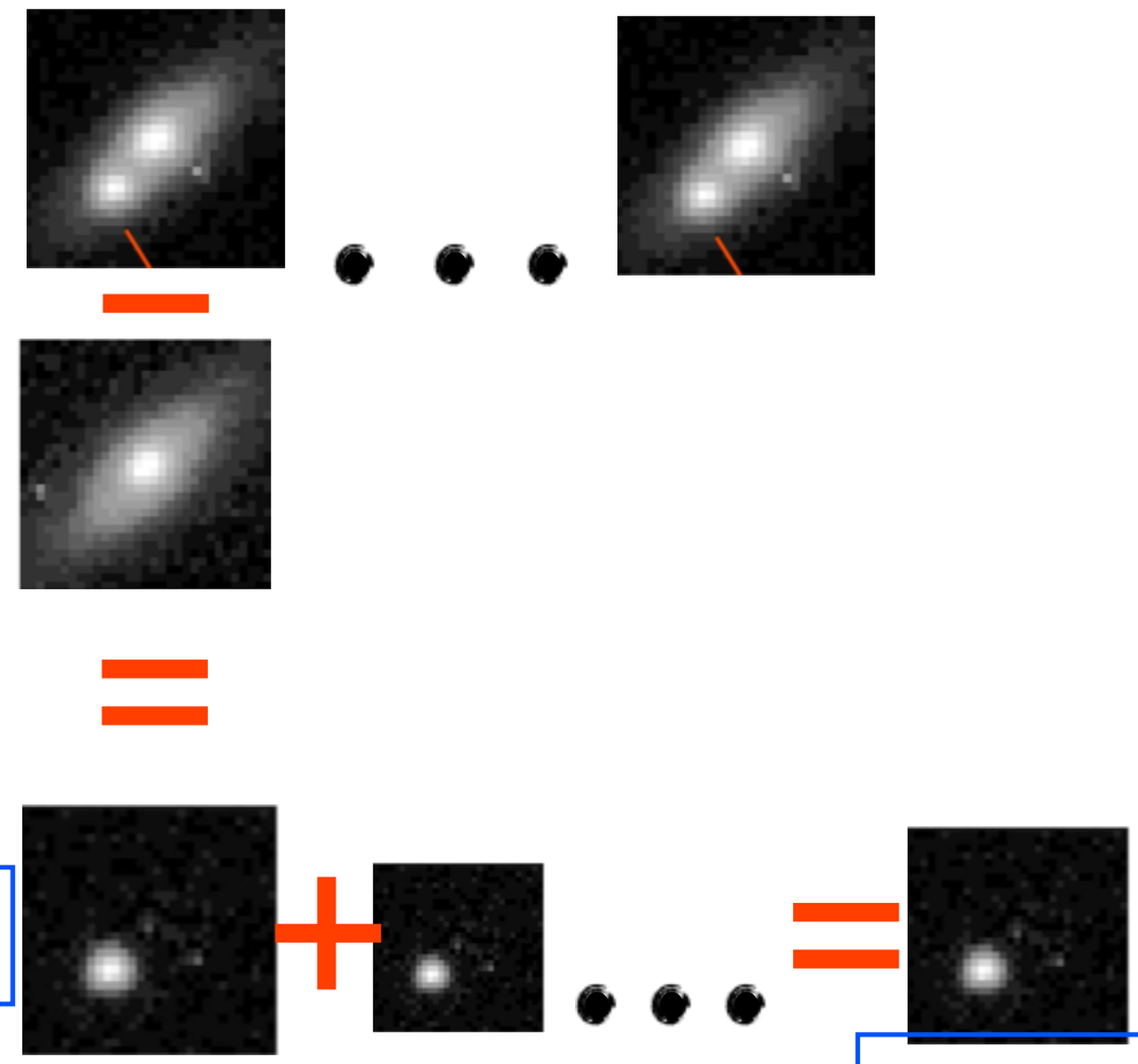
Saclay Pipeline:
-Subtraction (TRITON)
-Stacking
-Detection (SExtractor)

Subtraction of reference images from "current"

current images

reference image

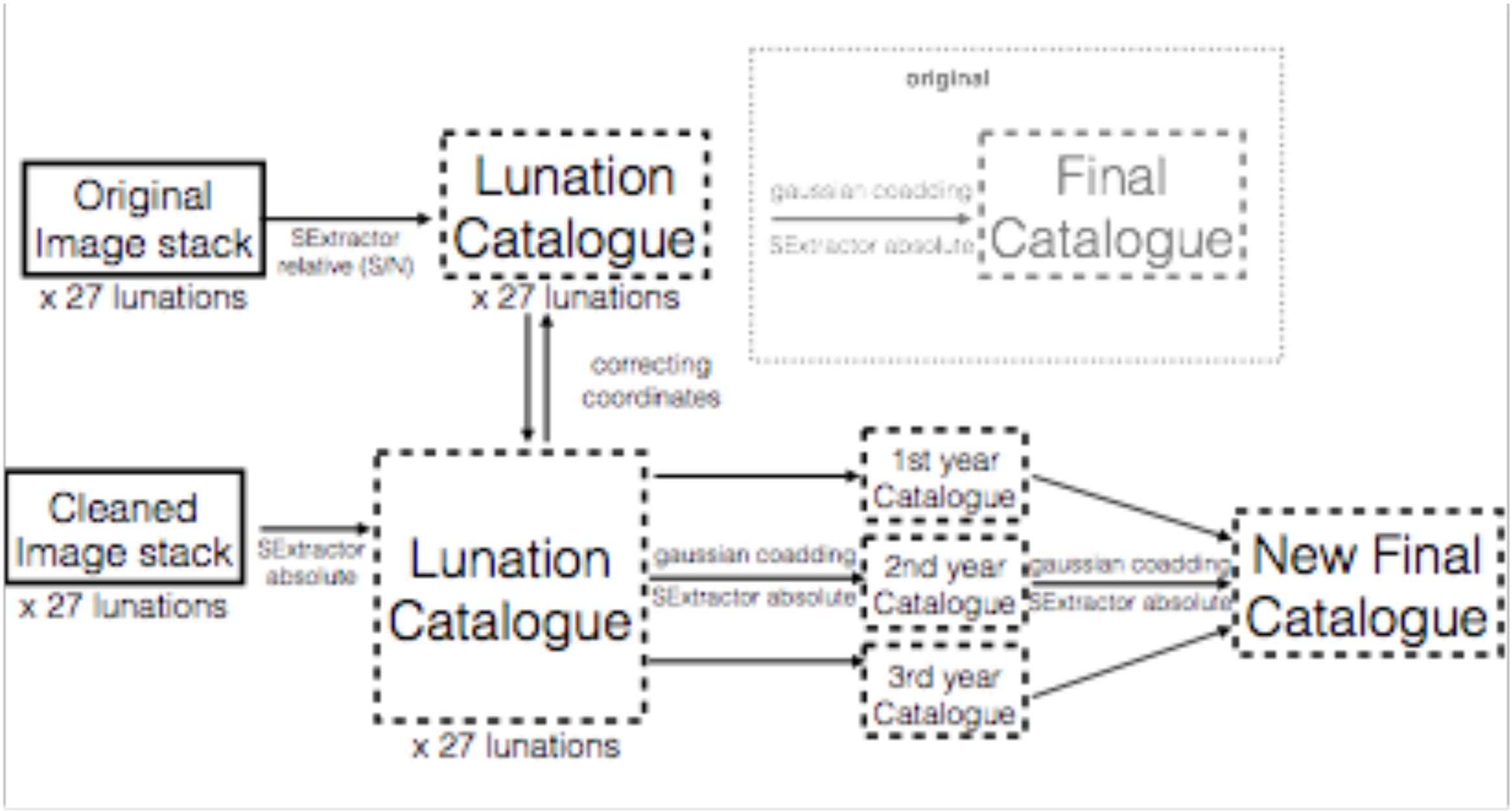
subtracted images



images on the same lunation
to increase S/N

lunation stacks

New detection strategy

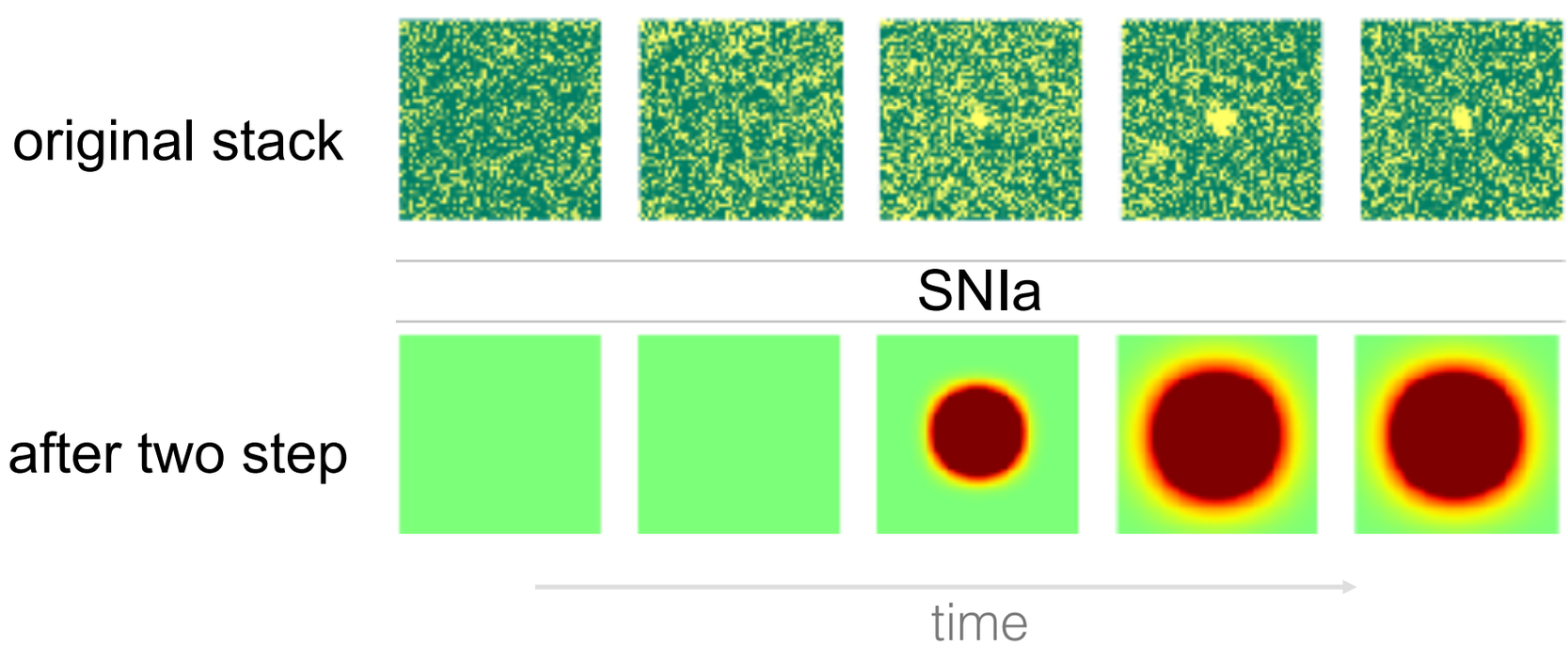


Step 2: varying noise

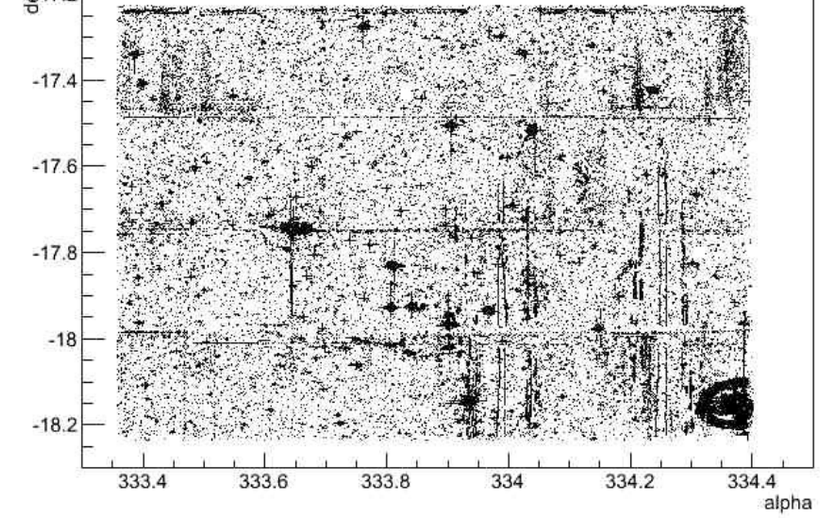
Non-stationary noise requires varying the threshold in the decomposition depending on the position of the analyzed pixel.

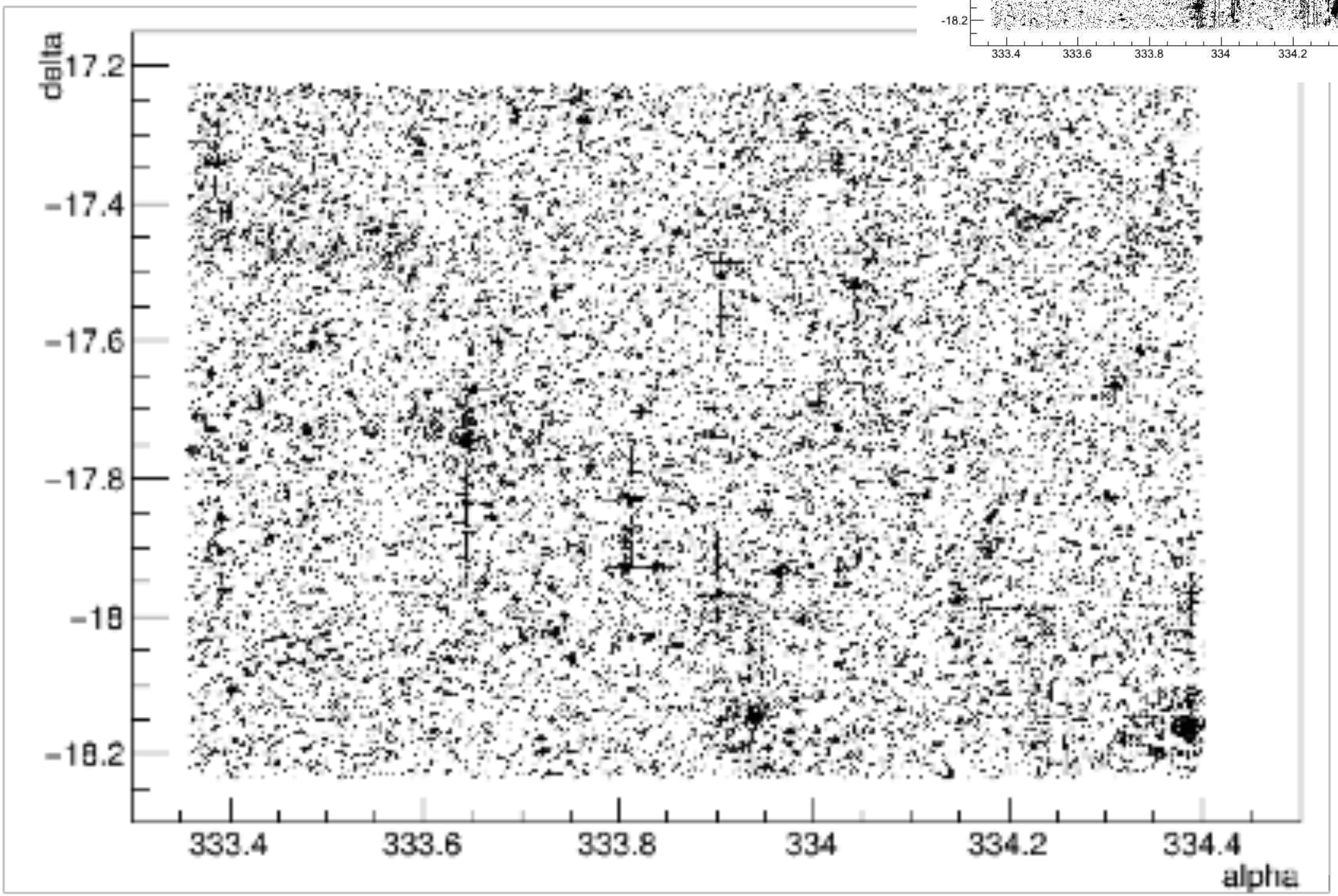
- noise: computed with sliding window 50x50 pixels
- dictionary: only starlet

All signals present in the output image can be considered as morphologically compatible with **circular-like** objects.



Improved detection map





A. Möller