

Photometric selection of type Ia SNe in the SuperNova Legacy Survey: Improving the detection of transient events

Anais Möller

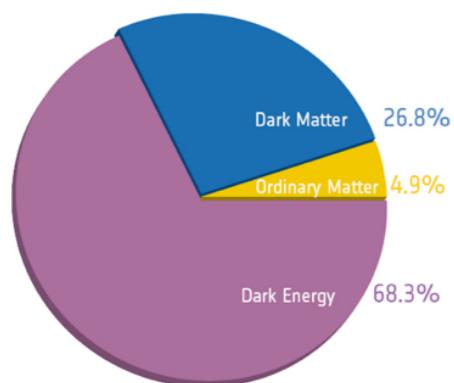
Advisor: Vanina Ruhlmann-Kleider
CEA Saclay (Irfu/SPP) - Université Paris Diderot

Cosmological context

Measurements of

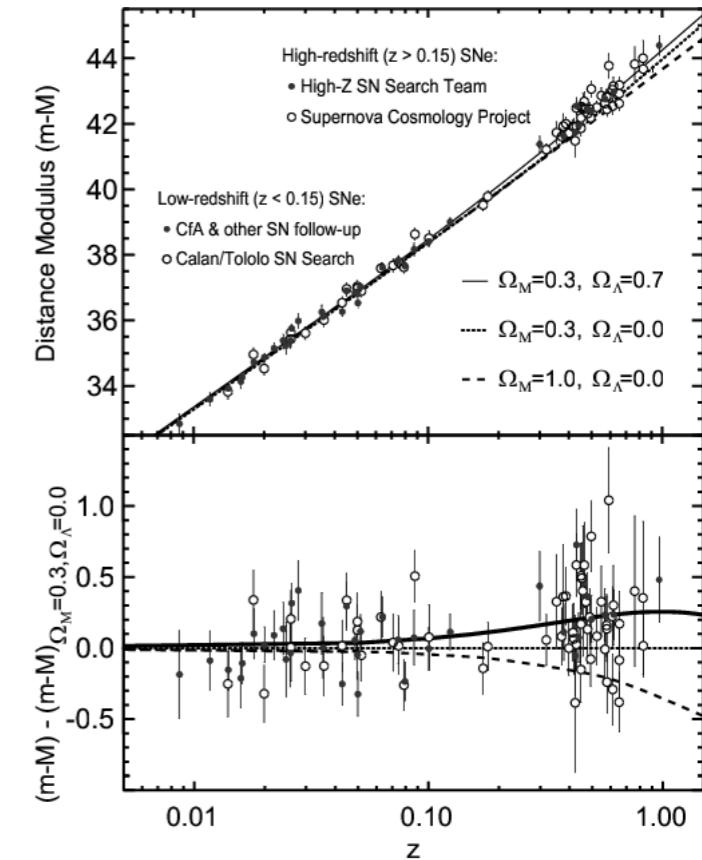
accelerated expansion of the universe with distant type Ia SNe.

(Perlmutter, Schmidt and Riess 1998)



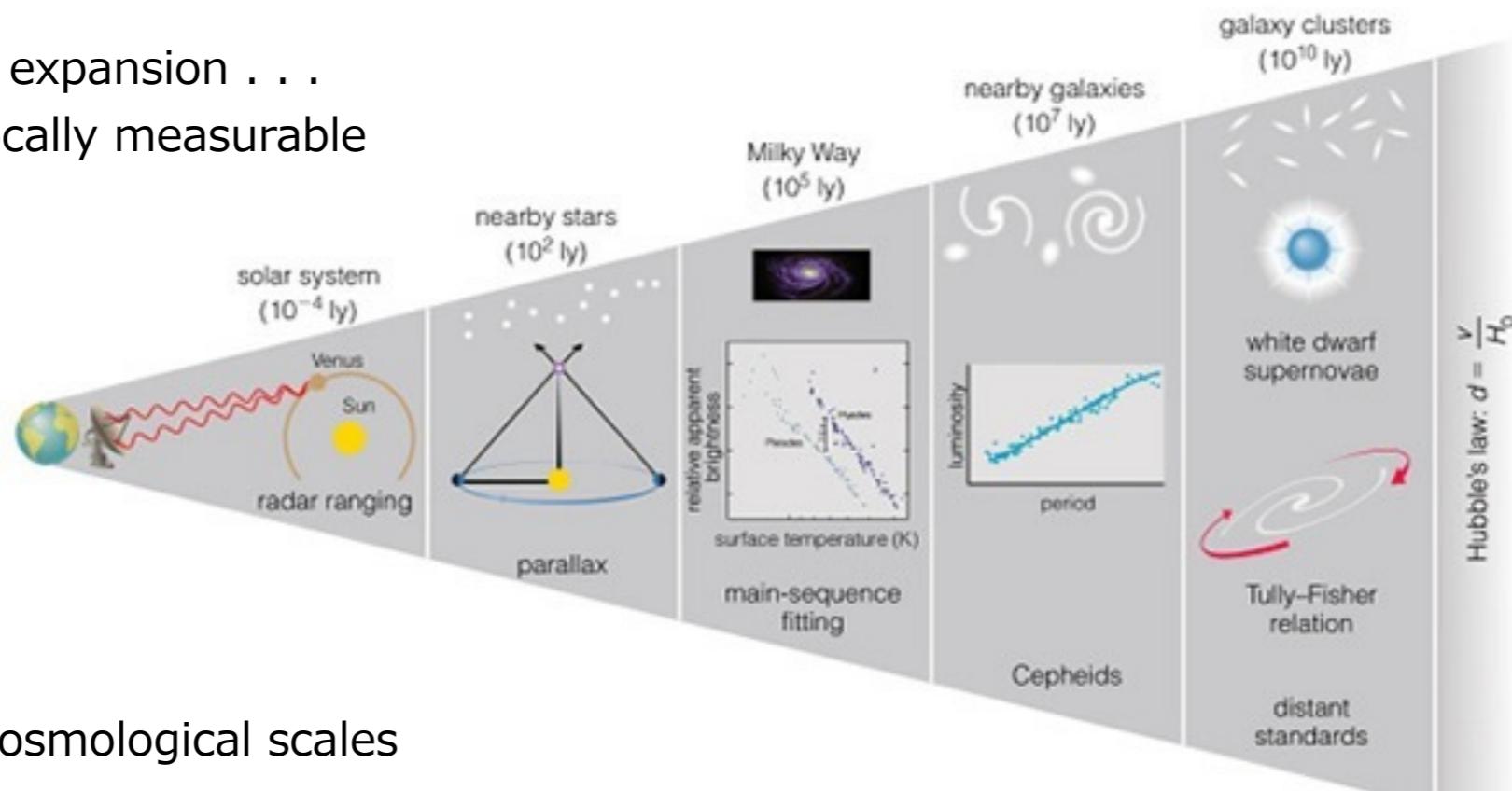
Dark Energy?
equation of state? is it time independent?
what is it? ???

Planck 2013 $w = -1.13^{+0.13}_{-0.10}$
 $\Omega_\Lambda = 0.686 \pm 0.020$



The distance ladder

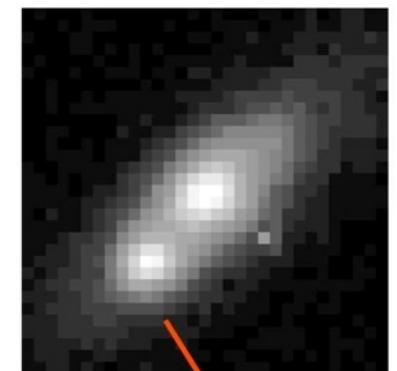
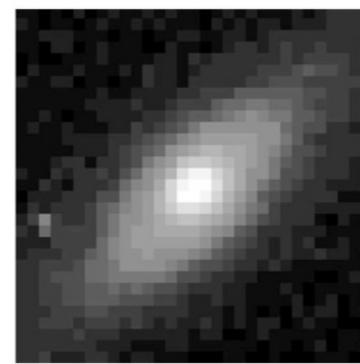
Accelerating universe expansion . . .
not locally measurable



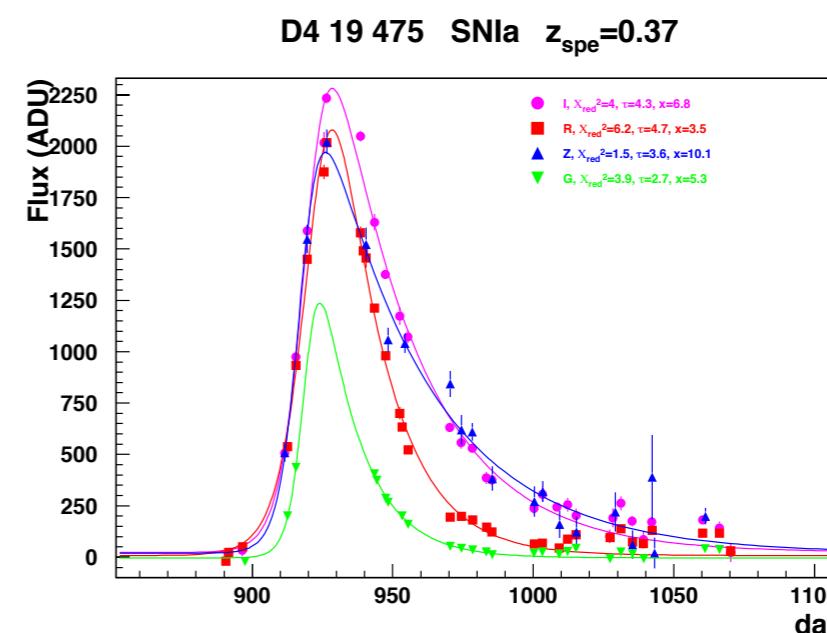
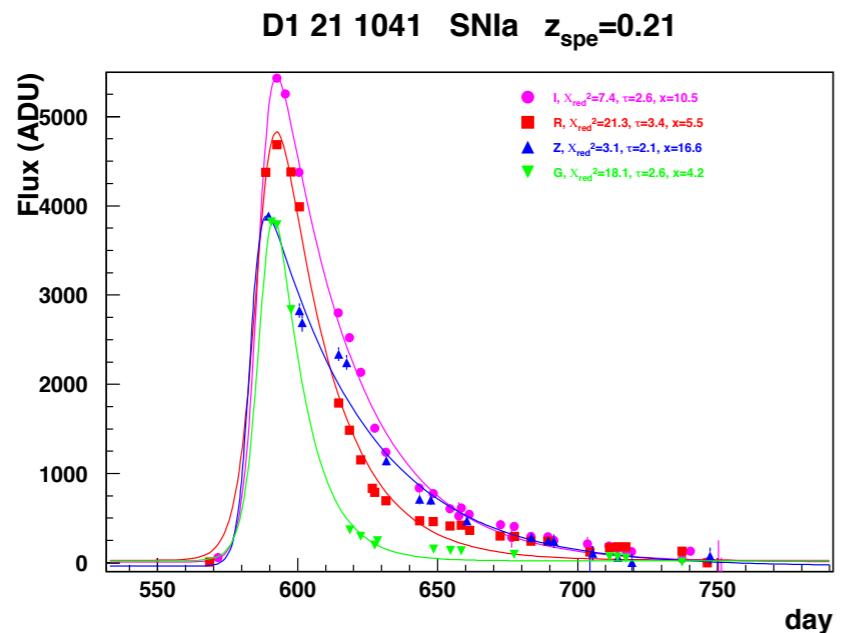
for the theorists:
but "very" recent in cosmological scales

Supernovae

- Very luminous stellar explosions (**transient** events).
- Types: Ia (thermonuclear) and Ib, Ic, II (core collapse).
- Homogeneous **spectral** and **photometric** properties.



Explosion of 04D1dc



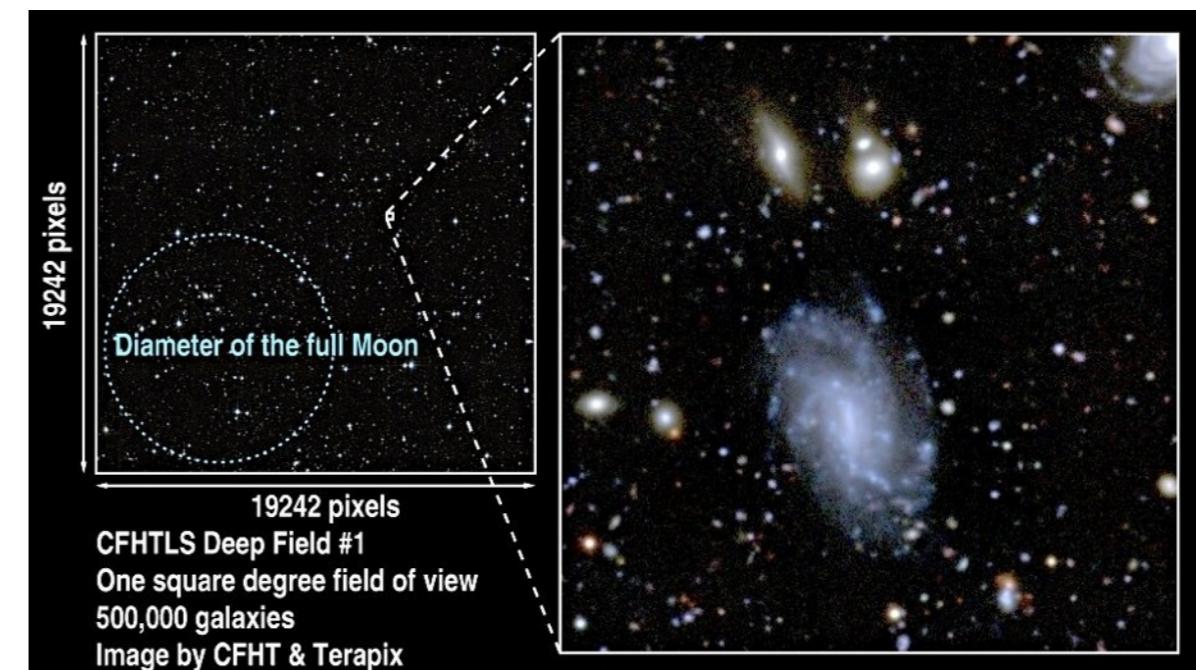
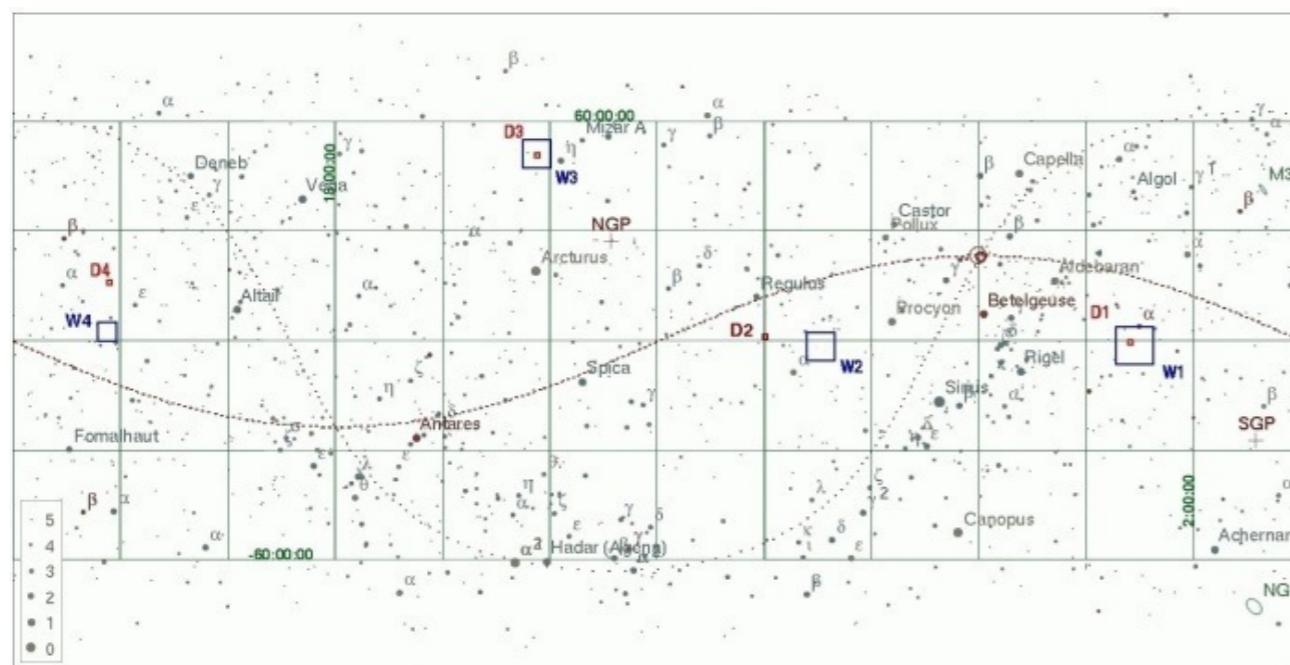
- Similar luminosities → characteristic light curves!

Standard candles



SuperNova Legacy Survey (SNLS)

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

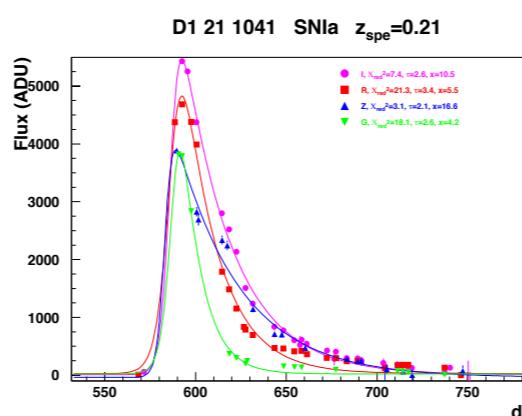


SuperNova Legacy Survey (SNLS)

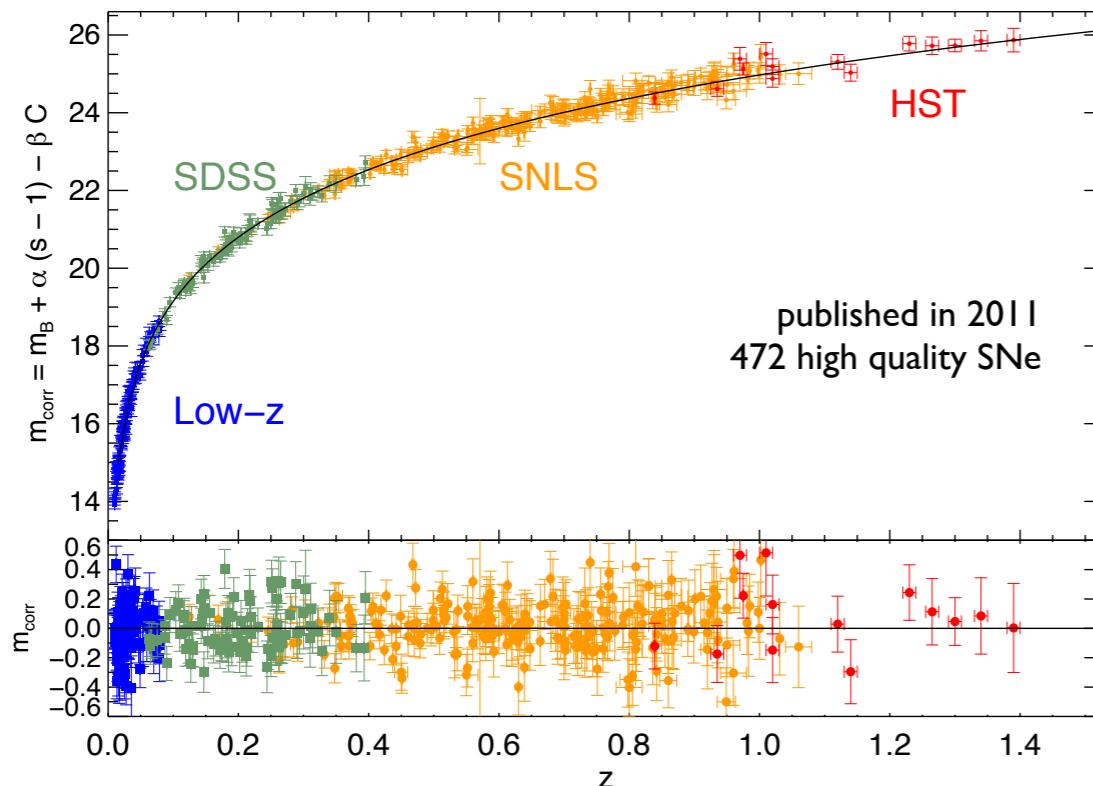
SNLS main goal: equation of state of Dark Energy!

SuperNovae

- Observations: **2003-2008**
- 4 broadband filters
- $0.3 < z < 1$

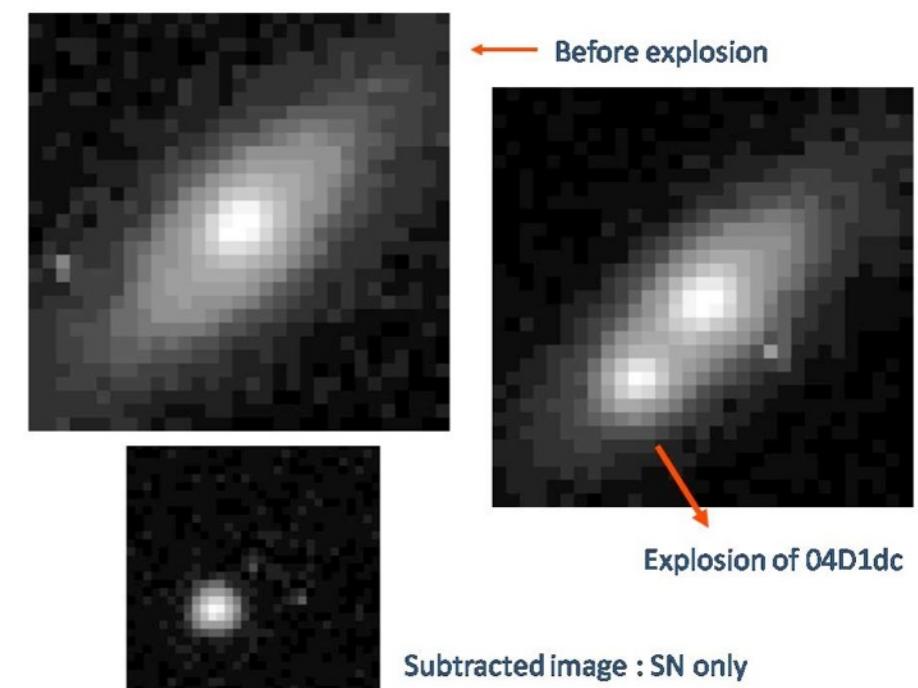


3-year data



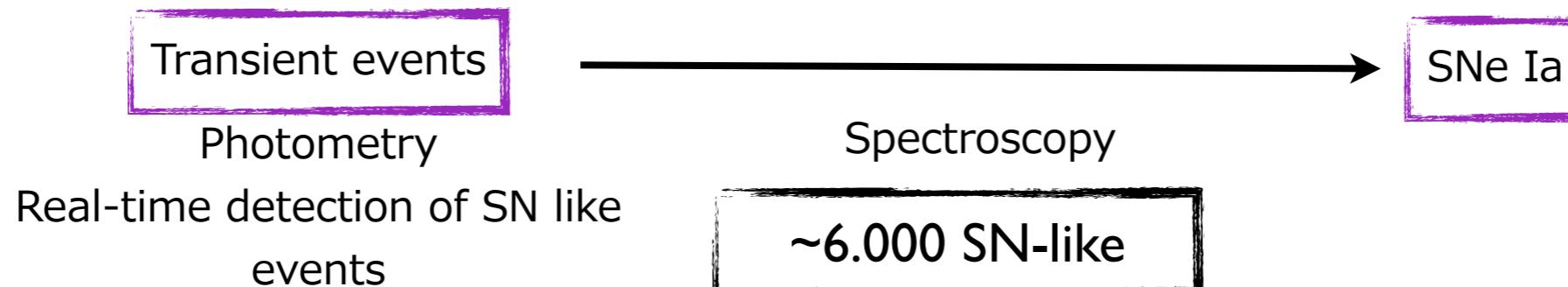
We want to detect:

- a transient object
- with luminosity equivalent to the one of its host galaxy



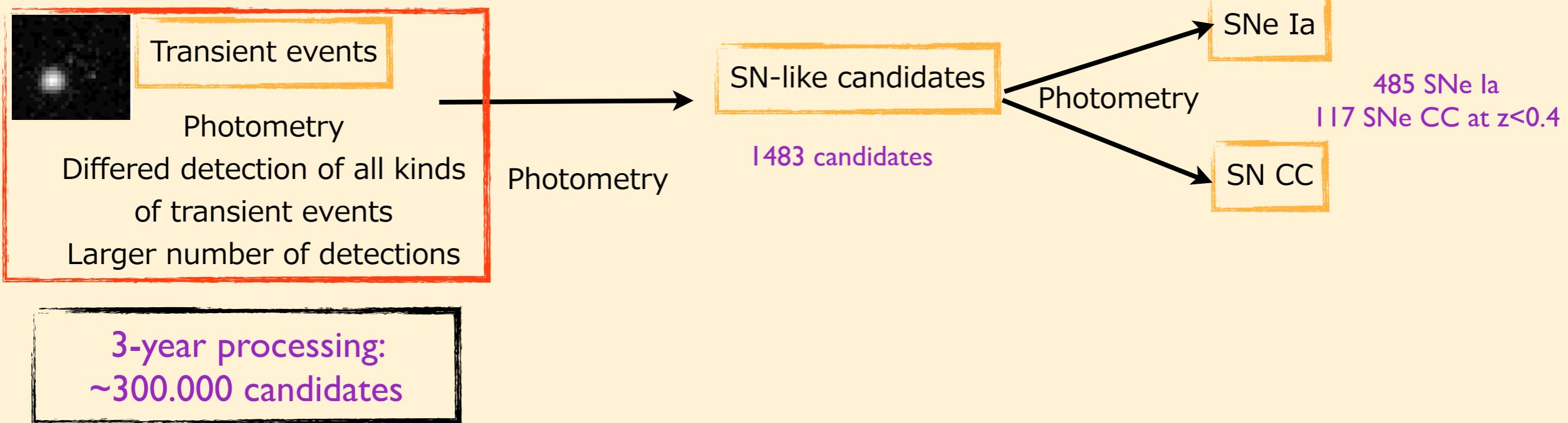
Analysis approaches: Standard and Photometric

Standard SNLS approach



Saclay group

Photometric approach



What you should take from the previous slide

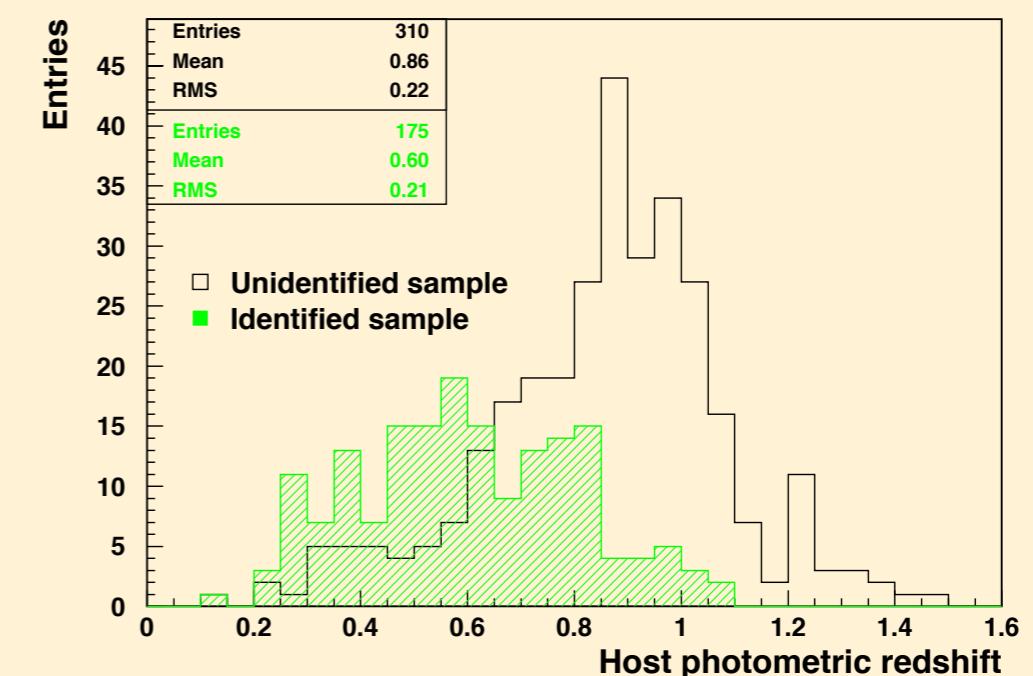
Standard SNLS approach

- Spectroscopy needed
- Real-time selection
- Lower systematics … usual method for measurements of SNIa in Hubble Diagrams.

Saclay group

Photometric approach

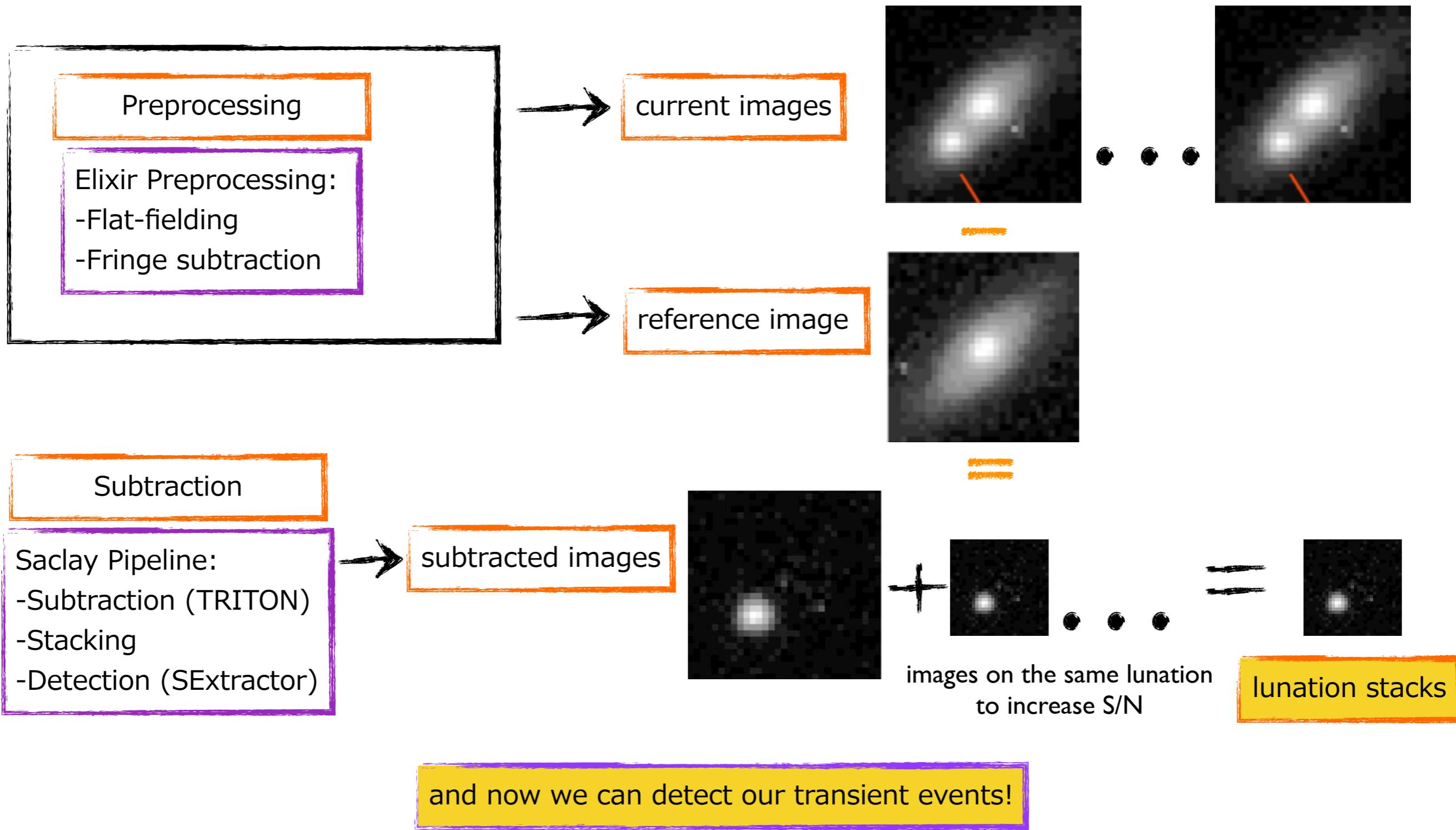
- **No spectroscopy** needed
- Data can be analysed **offline**
- Other types of **SNe** accessible
- **Larger redshift** coverage
- Larger systematics



Photometric detection

Transient events: we need to differentiate them from permanent objects

-> Subtraction of reference images from "current"



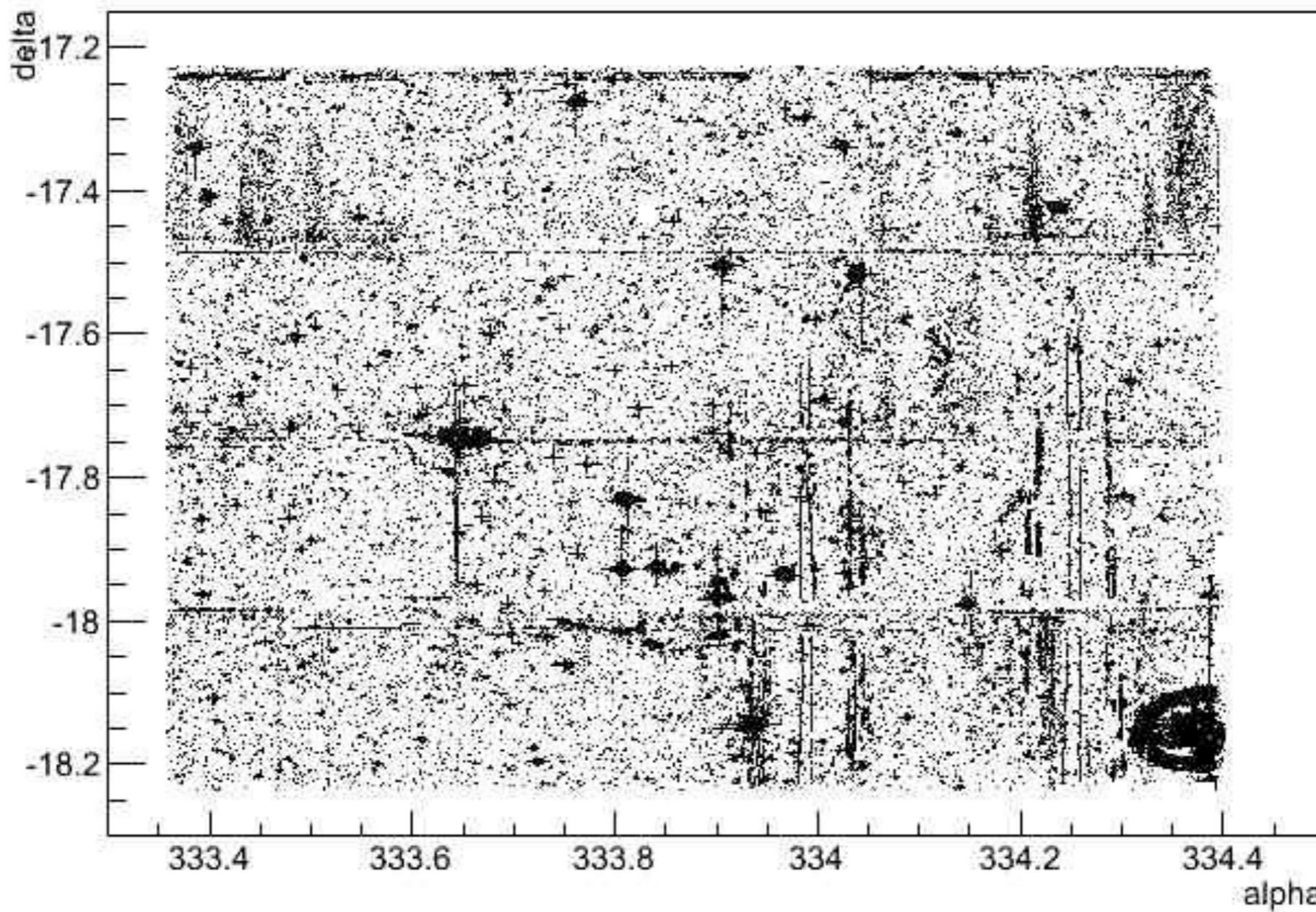
3-year photometric processing

4 fields @ 3-year processing

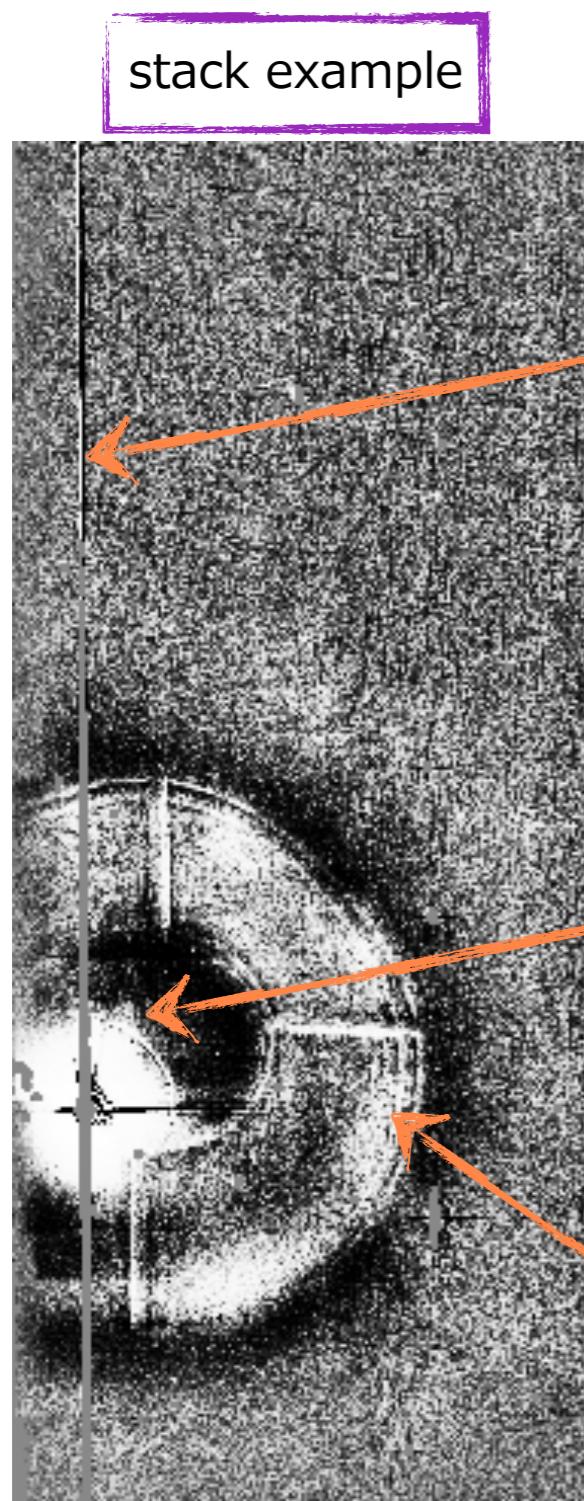
Detections: 302,987

SN-like candidates: 1,483

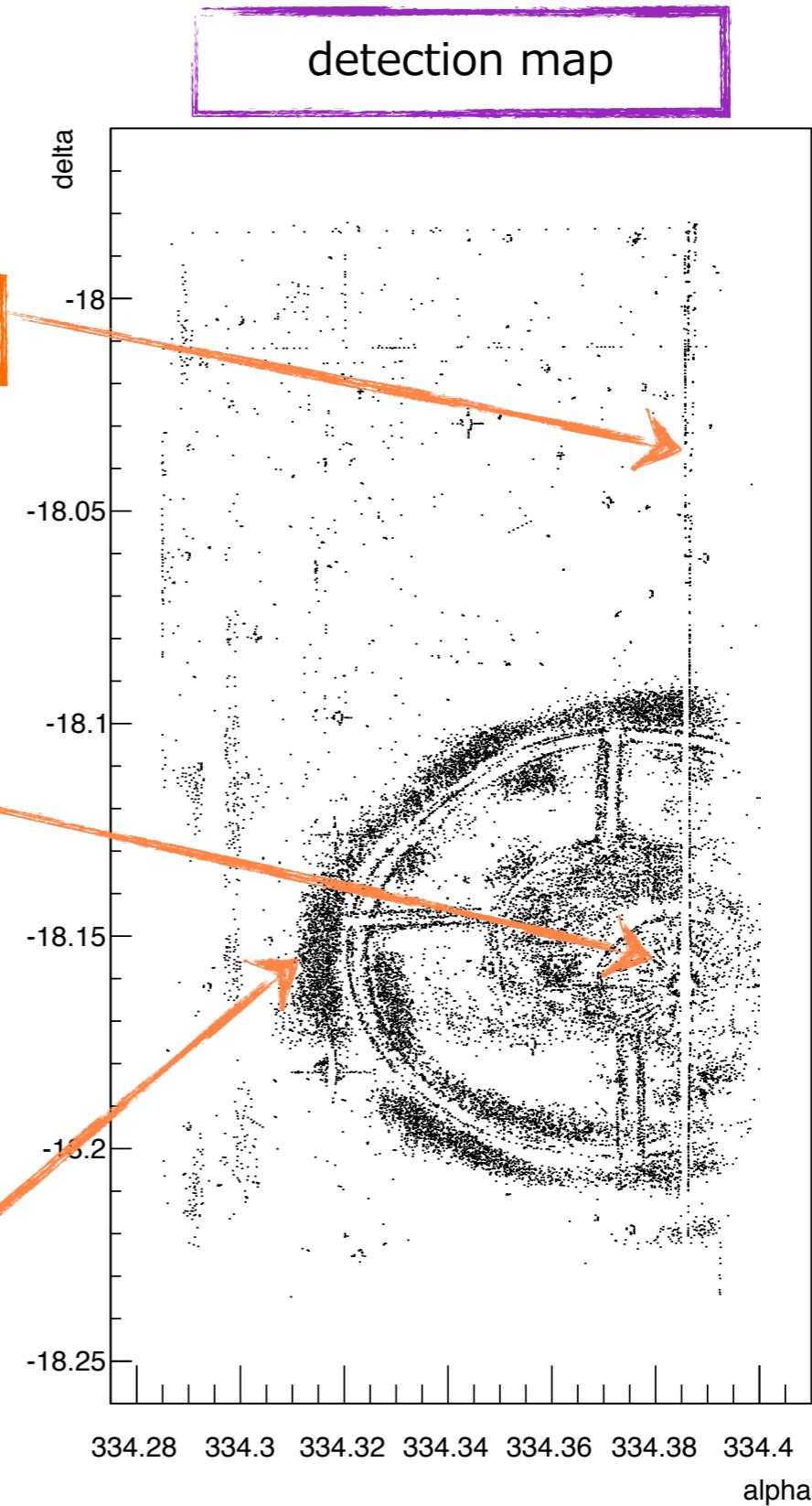
test sample: field D4 90,971



3-year photometric detection



problem
examples



Morphological Component Analysis



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

→ new method to reduce spurious detections at the lummation stack level

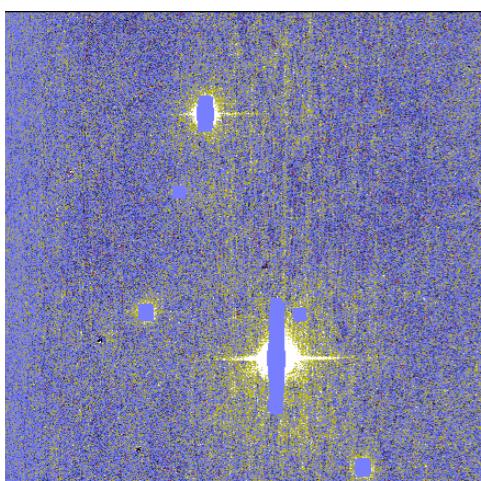
Hypothesis: a stack image can be decomposed completely in different “dictionaries”

An “atom”: is the an elementary signal-representing template (e.g. a sine)

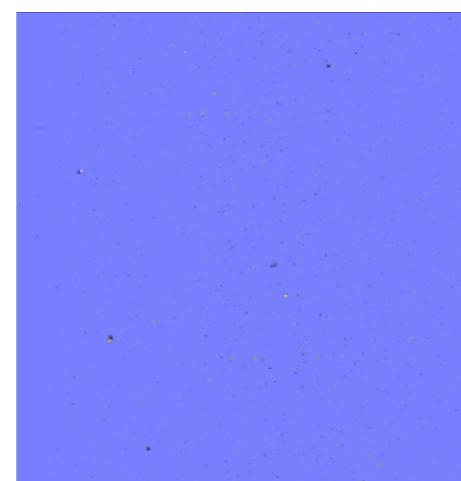
A dictionary: is a family of atoms that can be used to decompose a signal at different scales. (e.g. set of Sines at all frequencies)

We know some of the **defects** we have and which **type of signal an SN-type object** will be.

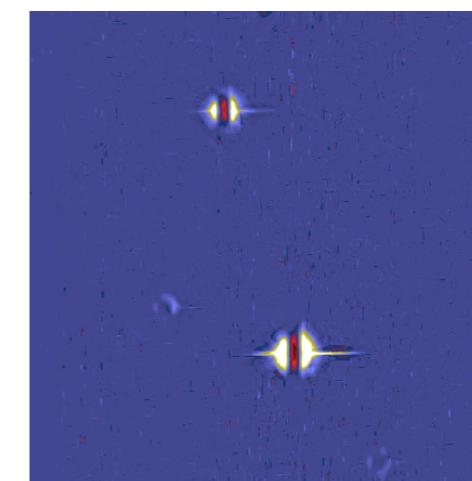
Search for “**circular shaped**” signals closer to second or third **scale**



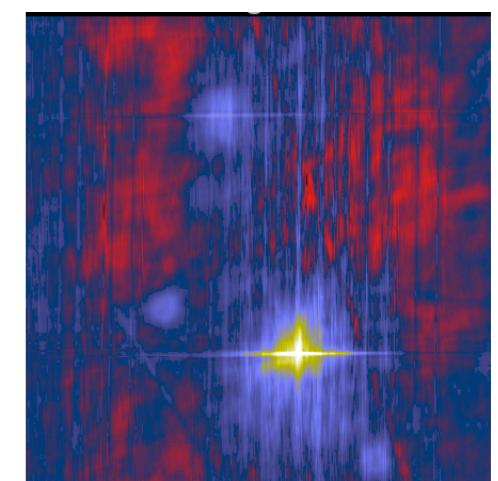
original image



wavelets



curvelet



ridgelet



modified starlet
bi-orthogonal



first treatment



We adapted a code from Starck et al. that uses morphological decomposition at different scales to reduce spurious signals

J.L. Starck, F. Murtagh, and J. Fadili, *Sparse Image and Signal Processing: Wavelets, Curvelets, Morphological Diversity*, Cambridge University Press, Cambridge (GB), 2010. (ISBN-10: 0521119138; 336-pp. monograph).

Characteristics

- Iterative
- Noise assumed stationary and gaussian
- Scales according to the transformation dictionary
 - Support masks

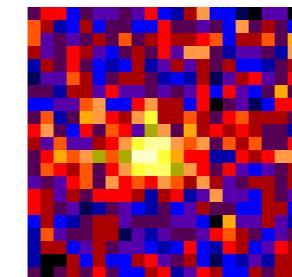
Dictionaries

- modified b3-spline isotropic undecimated wavelet
- bi-orthogonal wavelet
 - curvelet
 - ridgelet

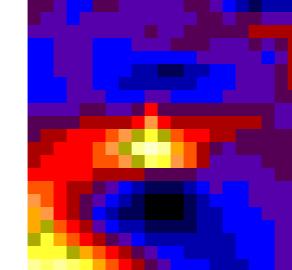
Noise map

- residuals

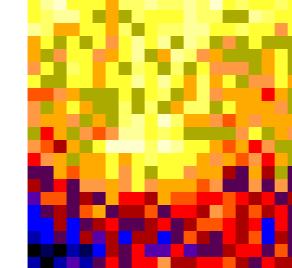
original stack



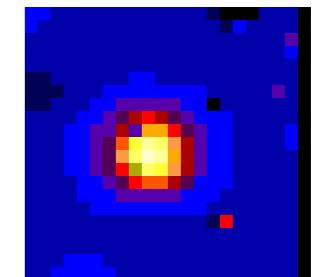
bi-orthogonal wt



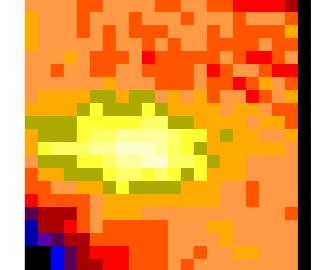
ridgelet



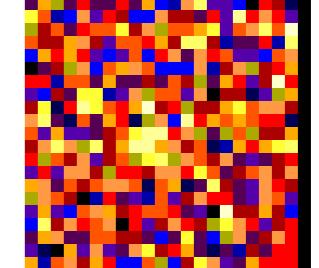
modified b3-spline isotropic
undecimated wavelet



curvelet



residuals



SN
D4-16-95

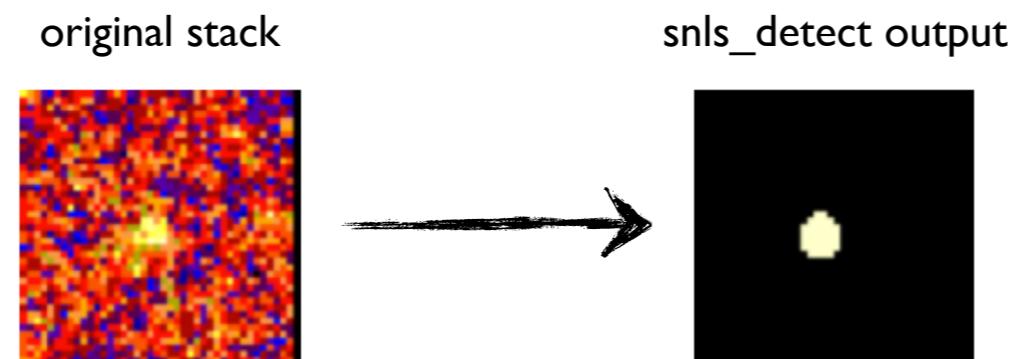
second treatment: snls_detect



Accounting for non stationary and non gaussian noise

snls_detect:

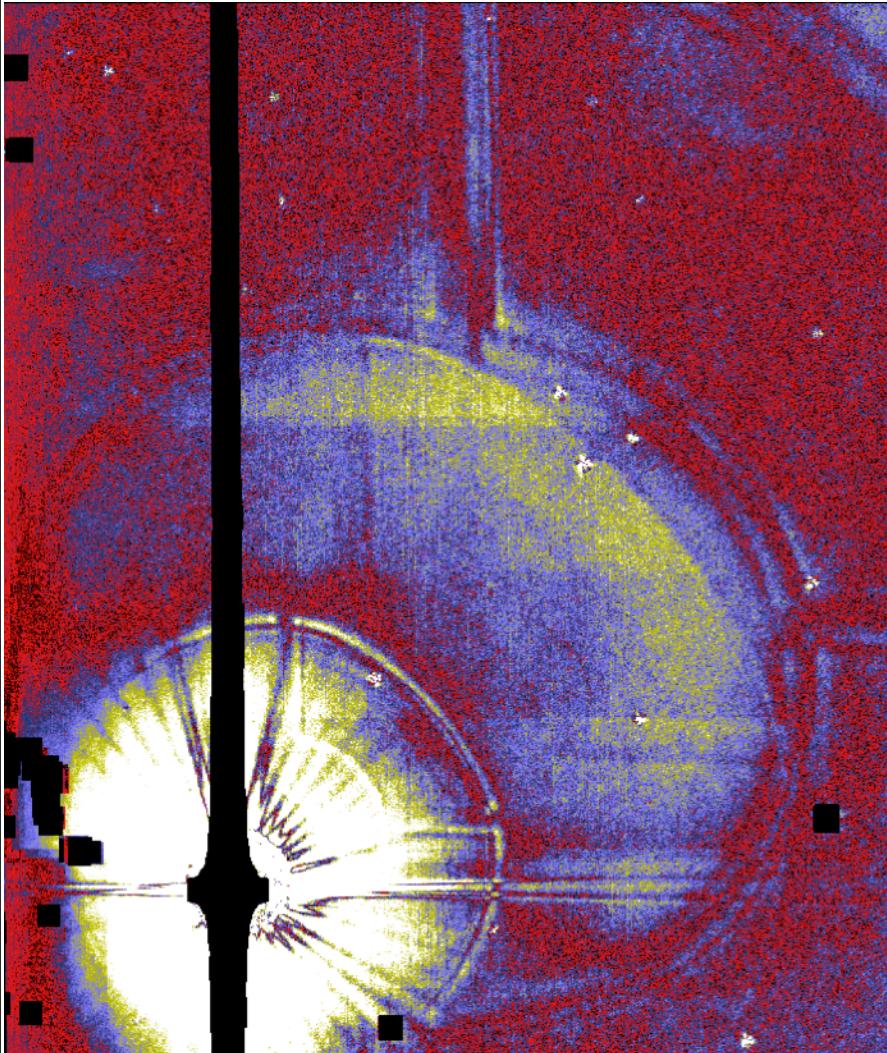
- takes advantage once again of **morphological information** with wavelets only
(first treatment decomposition is not perfect)
- supports **non stationary noise**
- reduces spurious detections due to imperfect subtractions (**ying-yangs**)



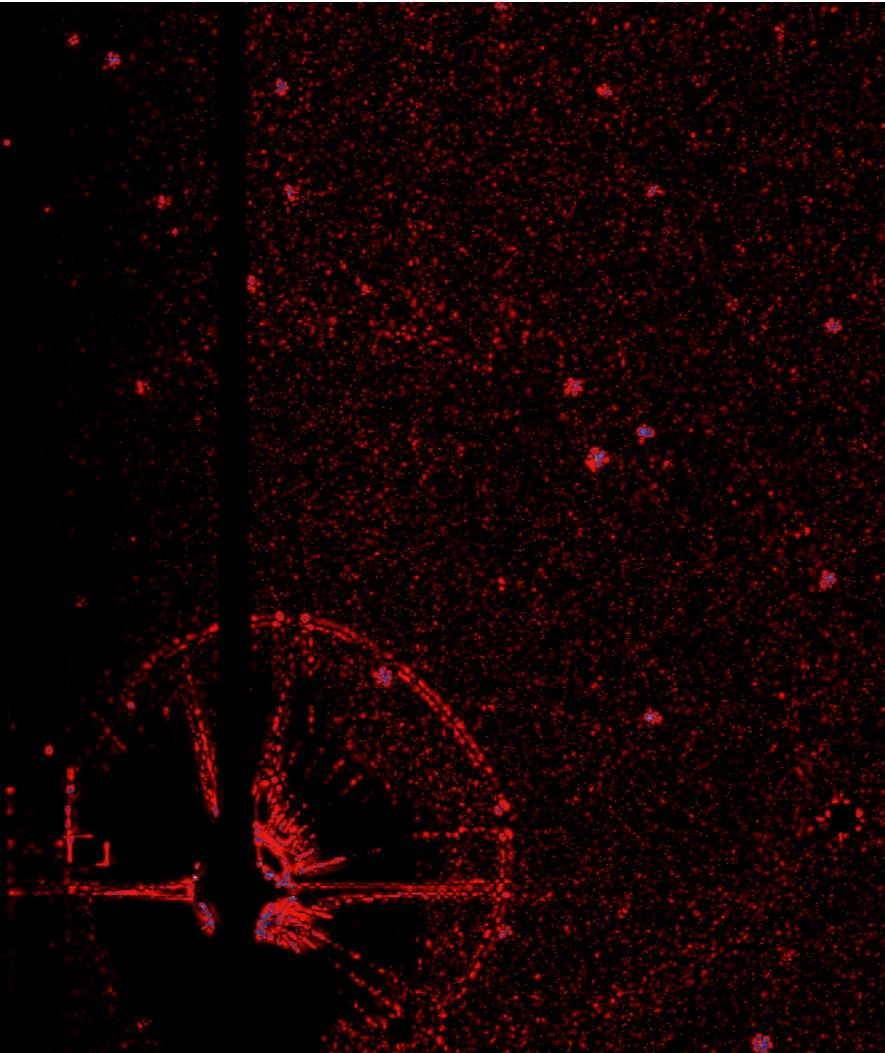
- all objects output by snls_detect are detection candidates

cleaning stacks

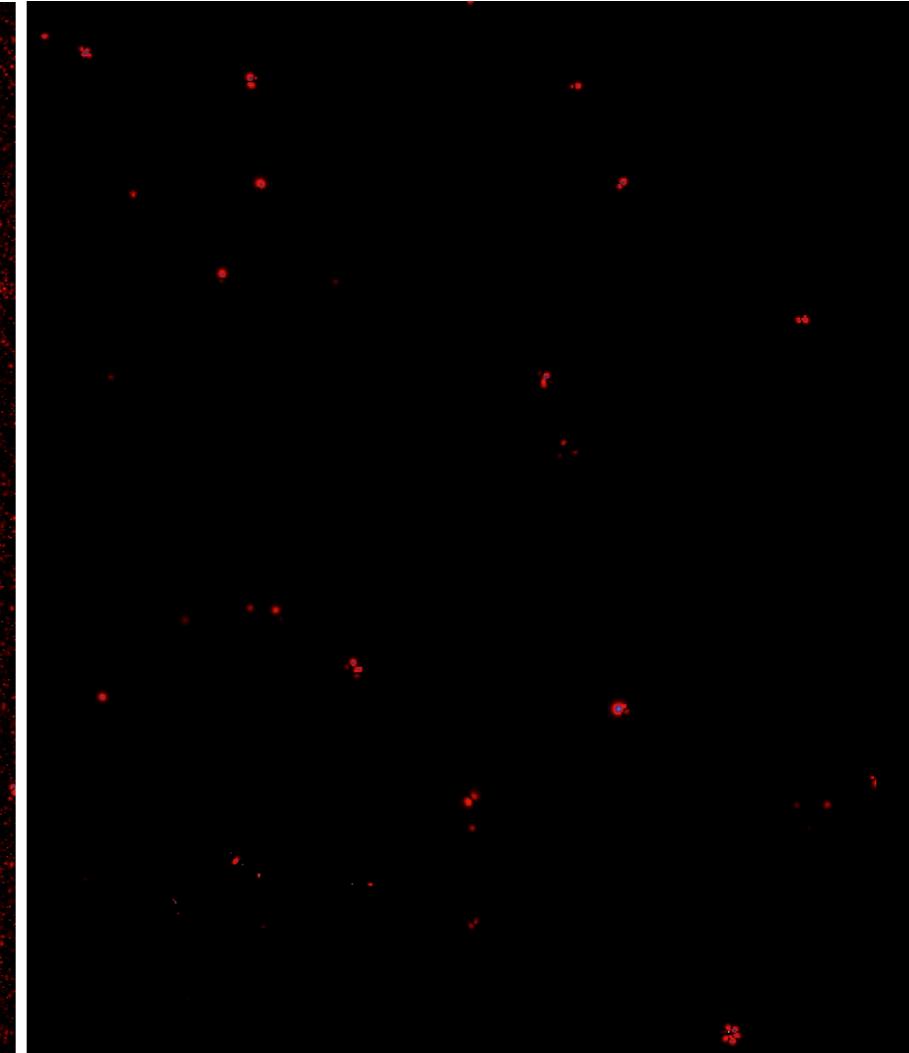
D4 CCD 00 RUN 10



original stack tile



after first treatment



after snls_detect

detections on ccd 00
and run 10:
1597

detections on ccd 00
and run 10:
452

3-year photometric processing

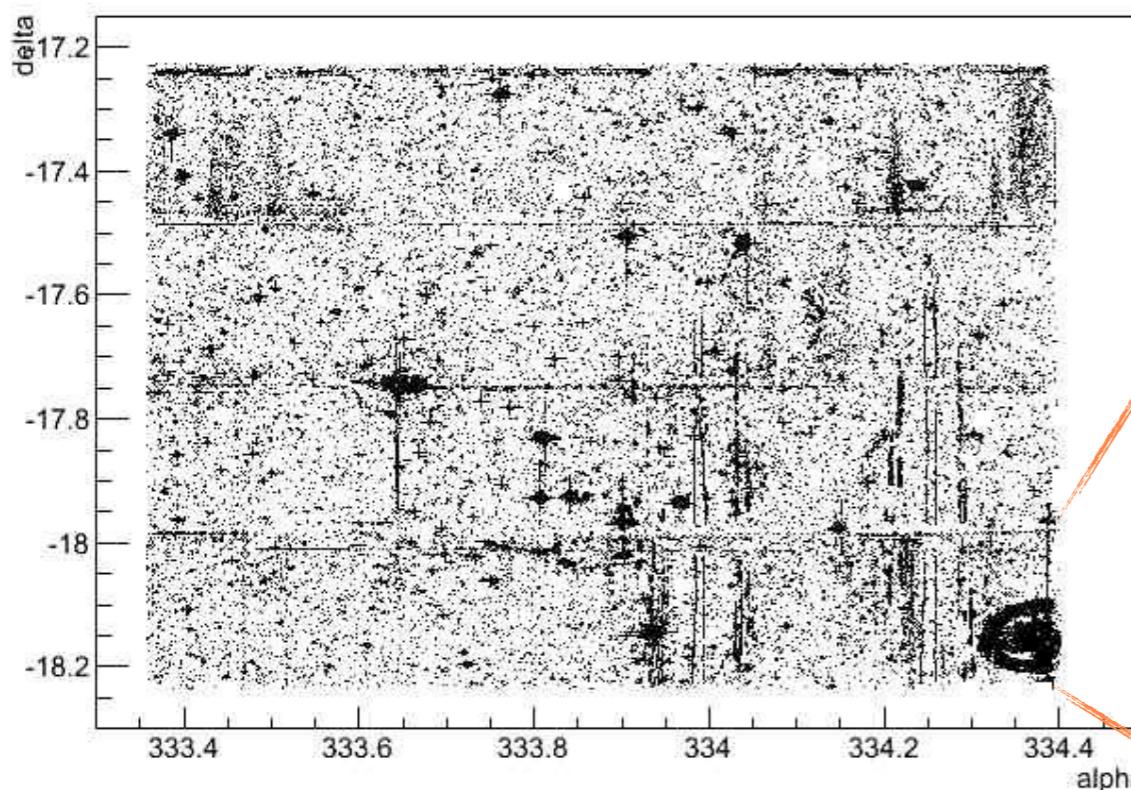
D4 CCD 00

4 fields @ 3-year processing

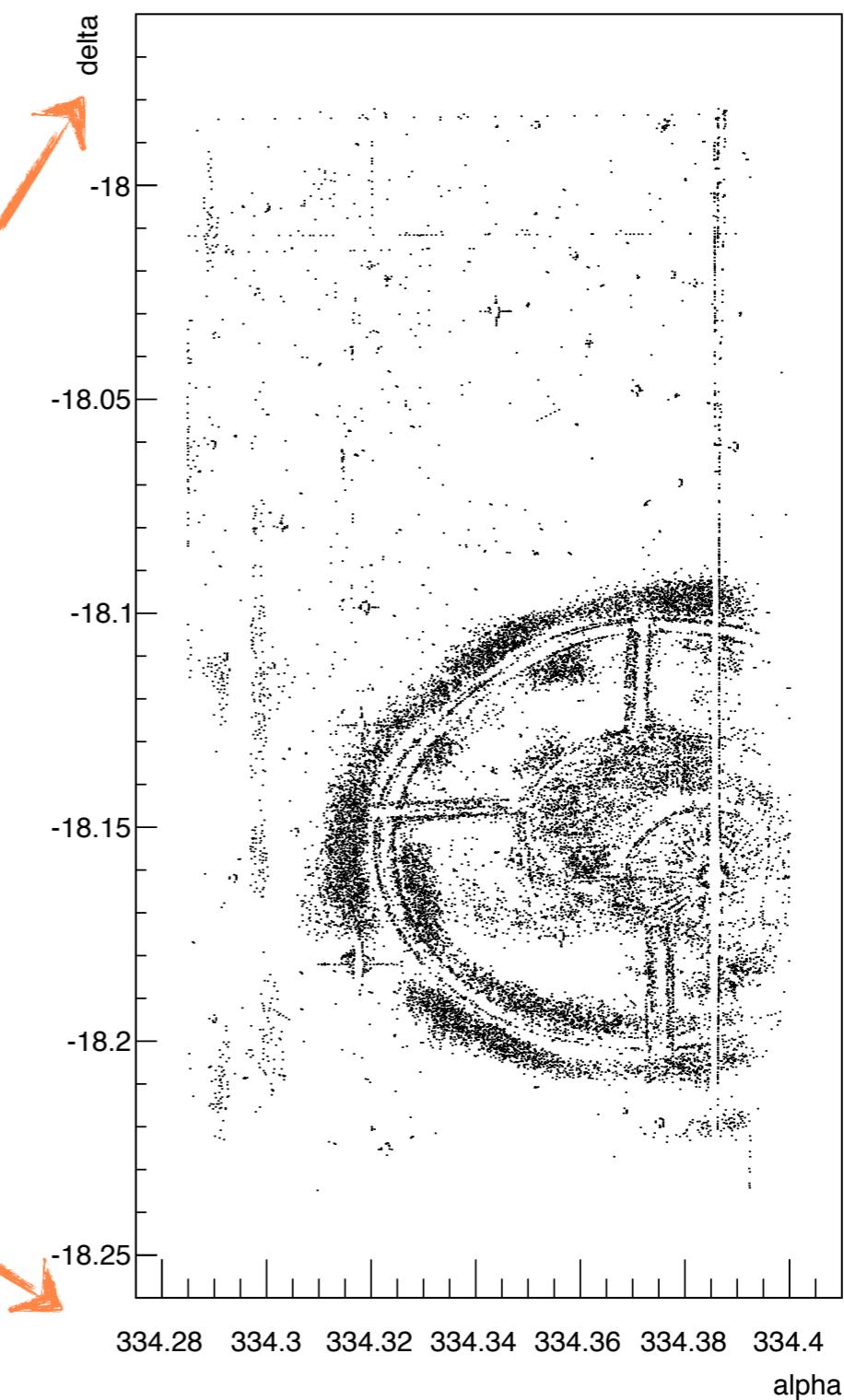
Detections: 302,987

SN Candidates: 1,483

delta:alpha



test sample: field D4 90,971

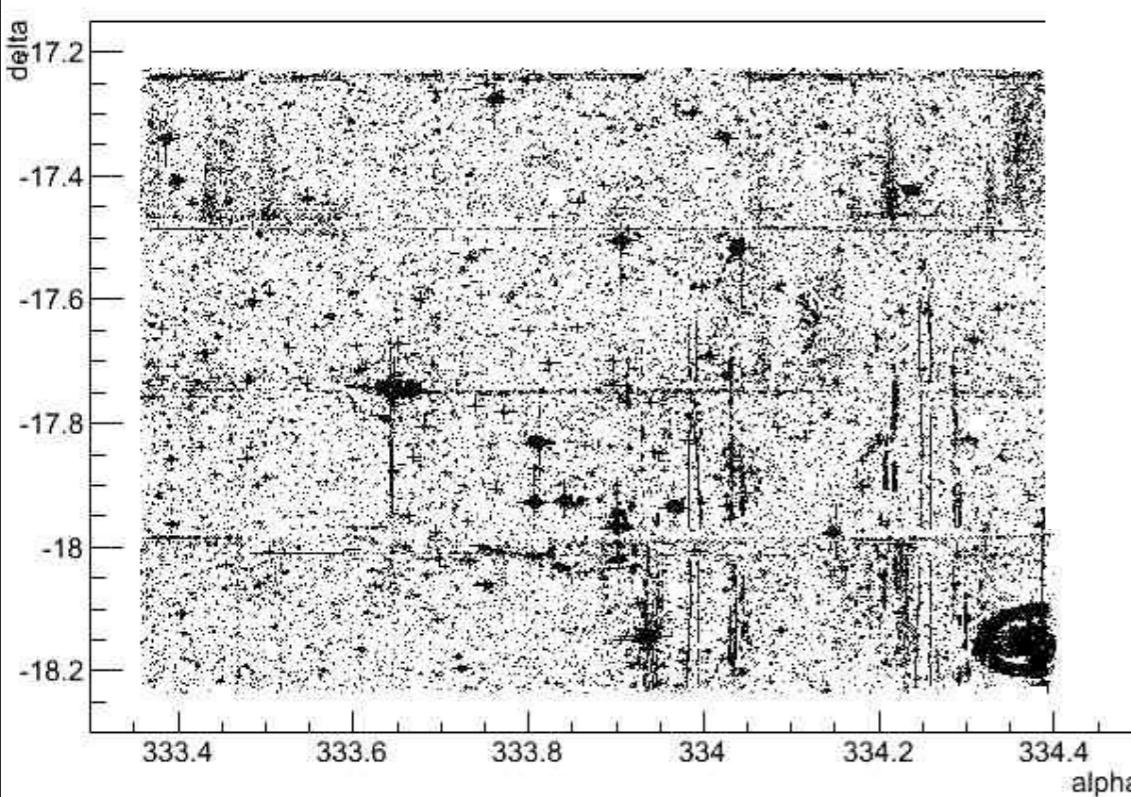


3-year cleaning detections

4 fields @ 3-year processing

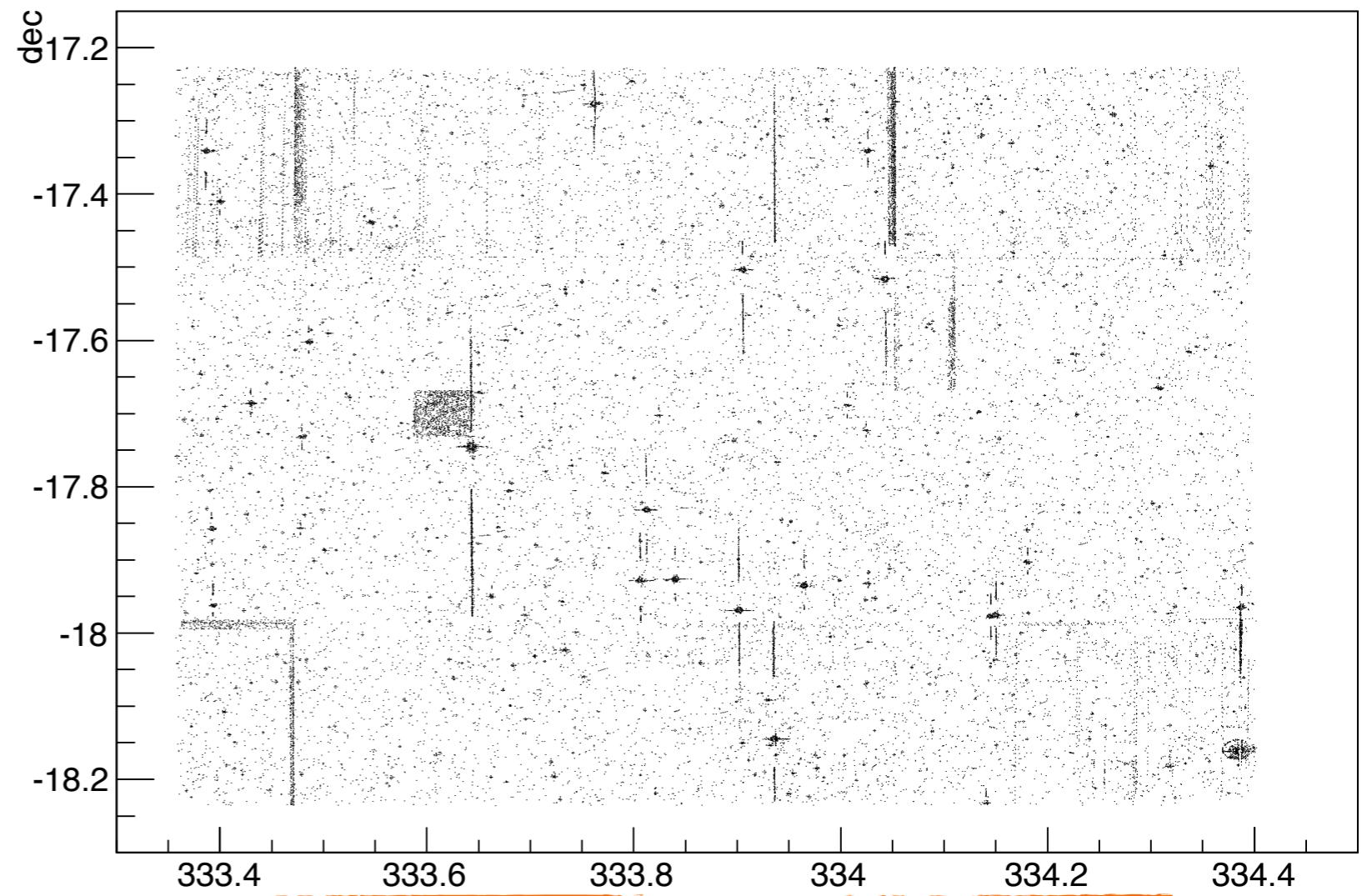
Detections: 302,987

SN Candidates: 1,483



test sample: D4 90,971

SN-like candidates 362



test sample after our cleaning

32,833

~ a factor 3 reduction!

loss of SN-like candidates ~7%

no photometric CC

3 photometric Ia (faint)

summary

first treatment

- Takes advantage of the powerful morphological component analysis
- Reduces spurious detections at the level of lamination stack images.

second treatment: `snls_detect`

- Suited for non-stationary noise processing
- Consistent with detecting objects in transformed images

3-year processing test sample D4:

before: **90,971**

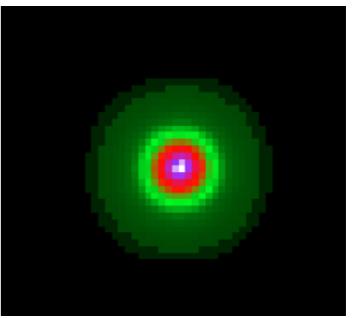
after `snls_detect`: **32,833**

loss of SN-like candidates ~7%

Morphological component analysis for detecting transient events



stay tuned . . .



Morphological component analysis for detecting transient events

publication on its way . . .

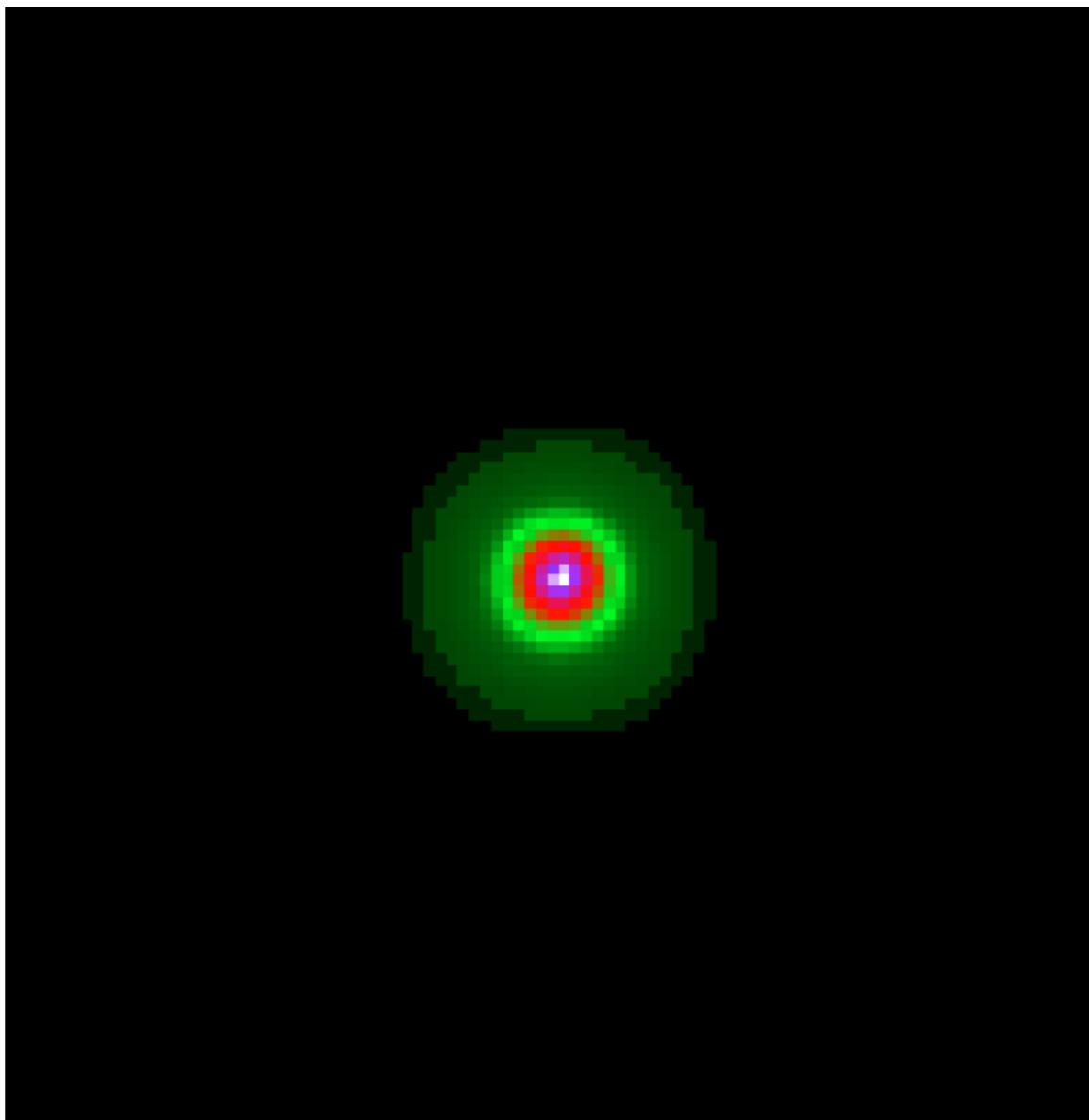
5-year SNLS photometric pipeline processing

Application to 5-year final differed processing where
instead of more of **500,000 detections we expect 150,000** (near 1/3)



and maybe around 800 photometric SNIa!!!

and do cosmology with only photometric data!



D4-01-2546