JOURNÉES DES THÉSARDS

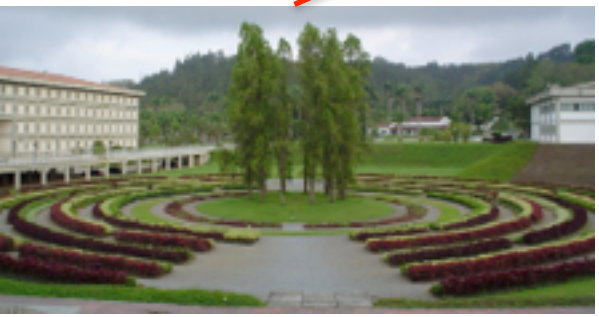
Photometric selection of type Ia SNe in the SuperNova Legacy Survey:

Improving the detection of transient events

Anais MÖLLER
Advisor: Vanina Ruhlmann-Kleider

Irfu SPP | July 2014

Who am I?



Universidad Simón Bolívar

Bac +5
Research project: quantum properties of a SU(2) model of the membrane

LPNHE PARIS

Internship
Photon plus jet cross section and purities in proton-proton collisions
√s = 7 TeV with the ATLAS detector

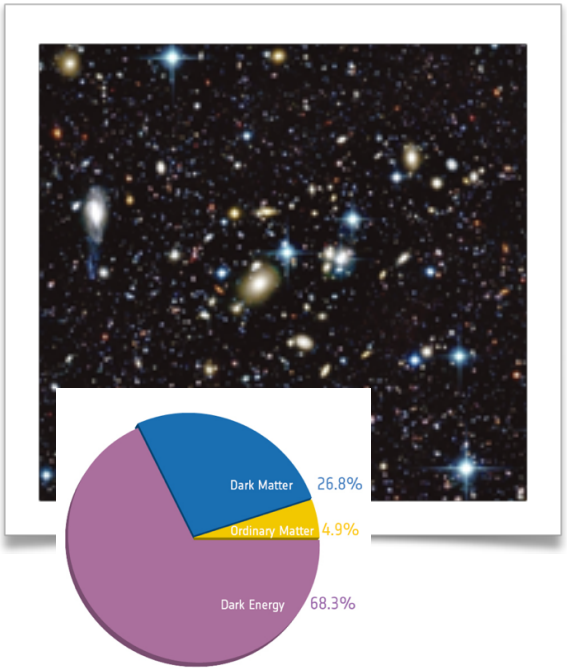
CEA

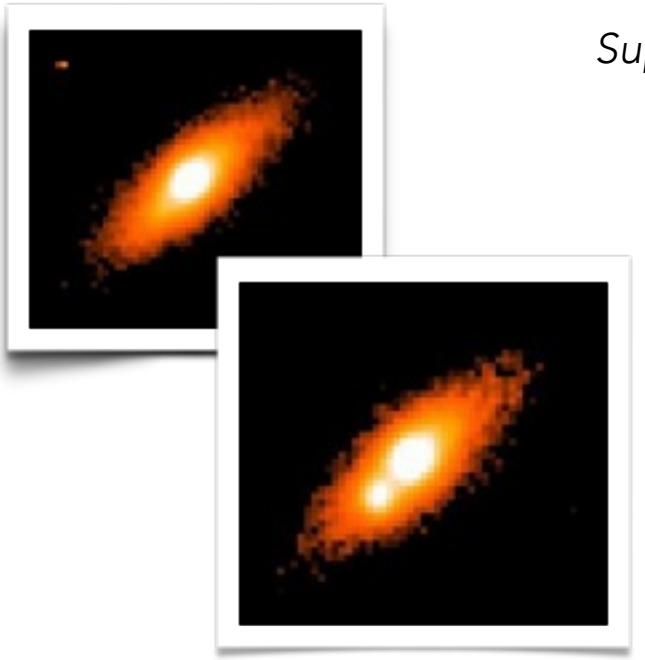
Internship
Data analysis on the SuperNova Legacy Survey

Theory → Particle physics → Cosmology

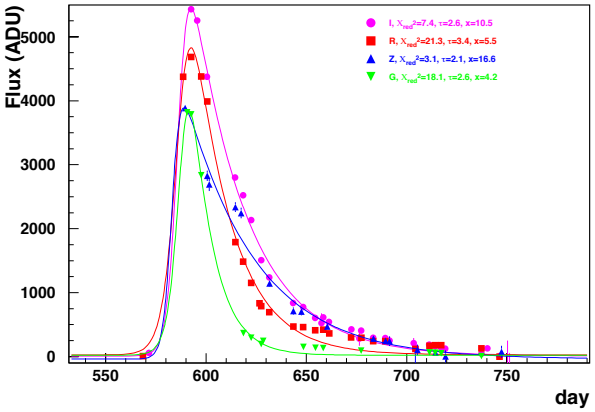
My PhD

Cosmologie à l'aide des supernovae de type Ia (SNIa) sélectionneés par photométrie dans l'expérience SNLS auprès du télescope Canada-France-Hawaii.





Supervisor: Vanina Ruhlmann-Kleider



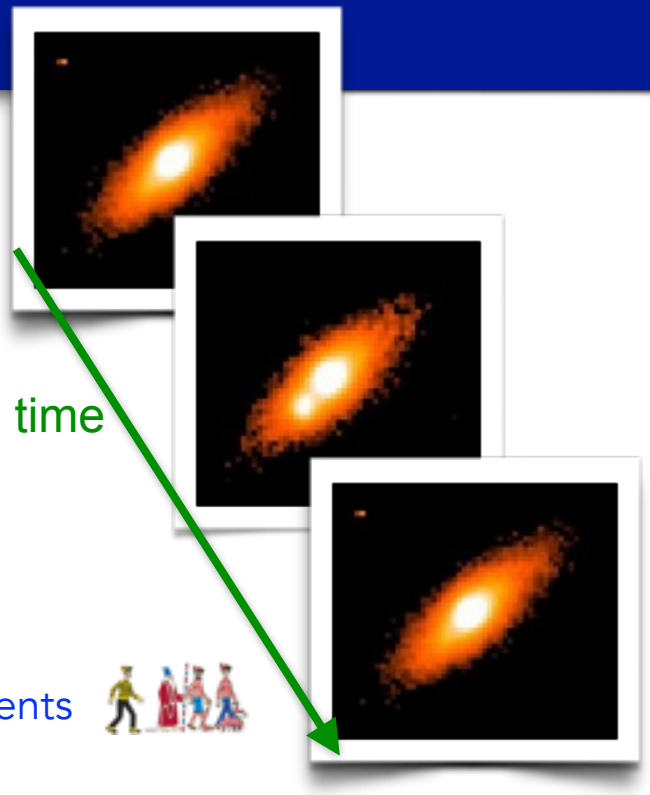
- *Cosmology*
  - ?Dark energy
- *Type Ia Supernovae*
  - ?Detection
- *Photometric SNIa*
  - ?No spectroscopy

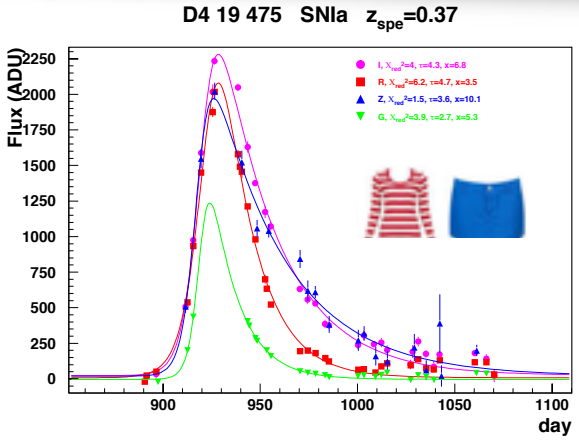
My **BIG** questions

Where is Waldo?
(where are my SNIa?)

My **BIG** questions

Where is Waldo?
(where are my SNIa?)

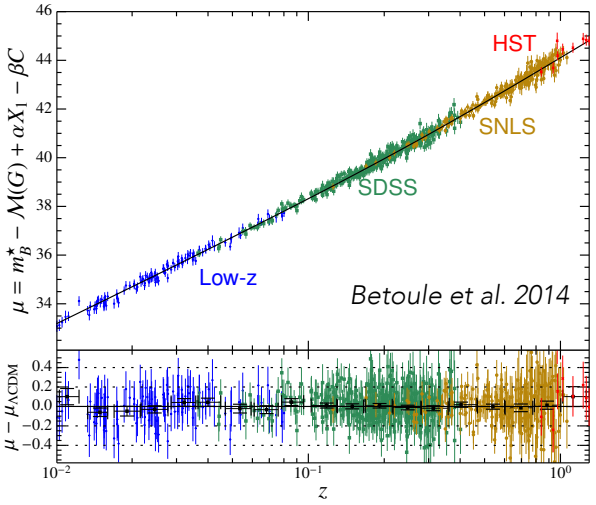




? Efficiency
- detecting transient events
- detecting SNIa

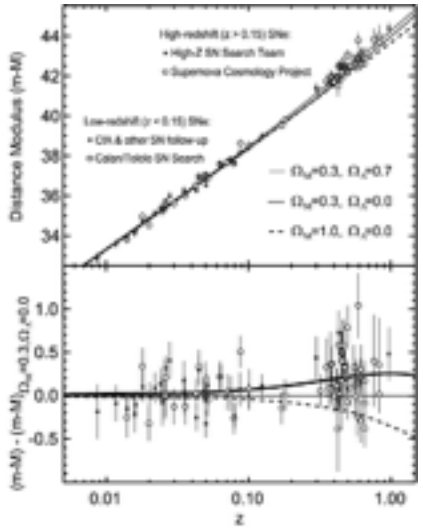
? Good coordinate resolution

? Efficiently identifying SNIa only from photometry



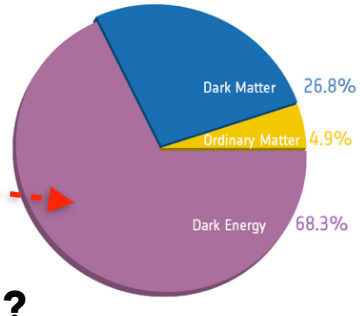
? Doing cosmology with SNIa using photometric redshift:
Hubble diagram->Measuring the expansion of the universe->Equation of state of Dark Energy

A brief morning breakfast "Cosmology" cereal



1998 measurements of **accelerated expansion** of the universe with distant **type Ia SNe.** (*Perlmutter, Schmidt and Riess)*

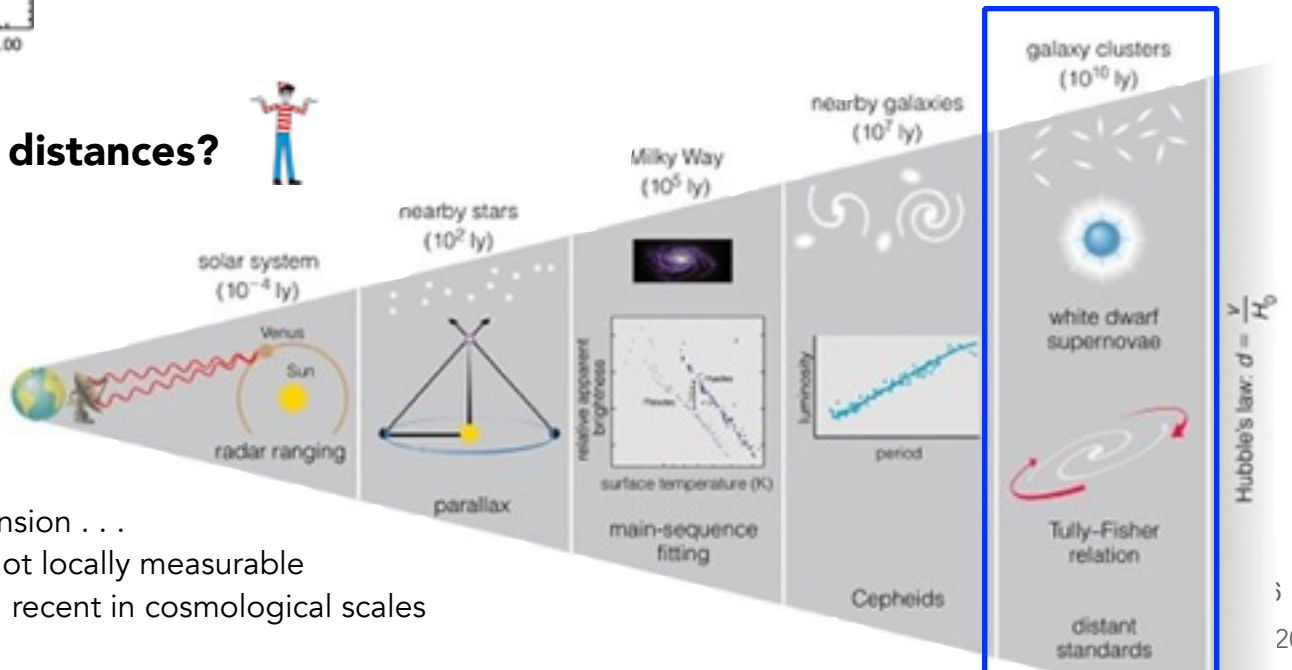
Why ?



Planck 2013

How do we measure expansion?

How do we measure distances?

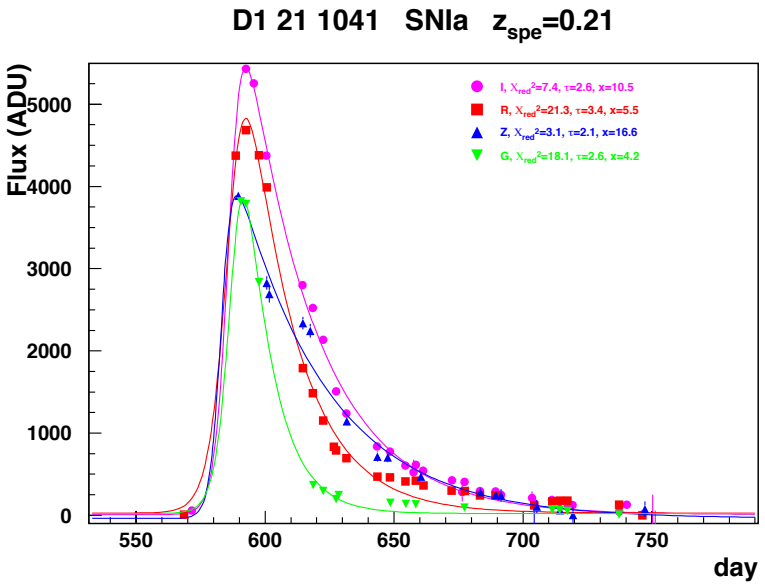


Accelerating universe expansion . . .
not locally measurable
for the theorists: but "very" recent in cosmological scales

Our distant standard: **SNIa**

Supernovae

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

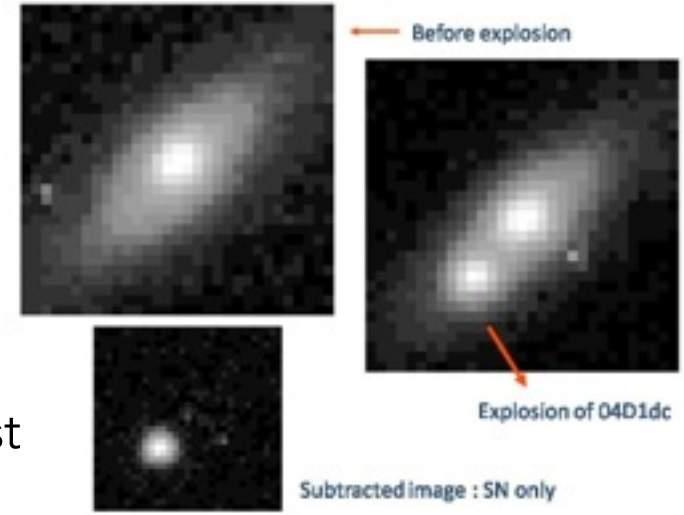
SNLS main goal: equation of state of Dark Energy!

- Observations: **2003-2008**

  SNLS 3:first three years (G.Bazin 2011, Betoule 2014)
  SNLS 5: all years

- **0.2 < z < 1**

We want to detect:
- a transient object
-with luminosity equivalent to the one of its host galaxy



SNLS analysis: standard vs. photometric

Standard SNLS approach

Transient events → SNe Ia

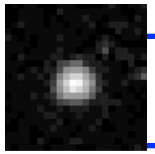
Spectroscopy

~6.000 SN-like

Photometry

Real-time detection of SN like events

Saclay SNLS group: photometric approach, e.g. SNLS 3



Transient events → photometry → SN-like candidates

Photometry

- Differed detection of all kinds of transient events
- Larger number of detections
- Larger redshift coverage

1483 candidates

SN-like candidates → photometry → SNe Ia

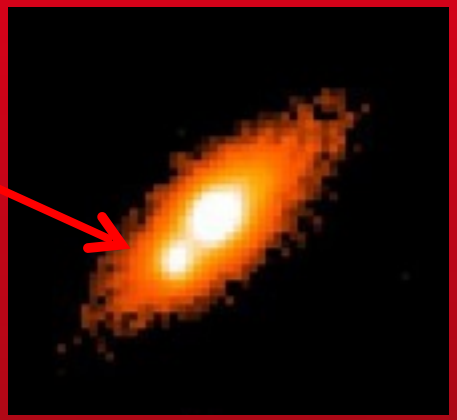
485 SNe Ia

117 SNe CC at z<0.4

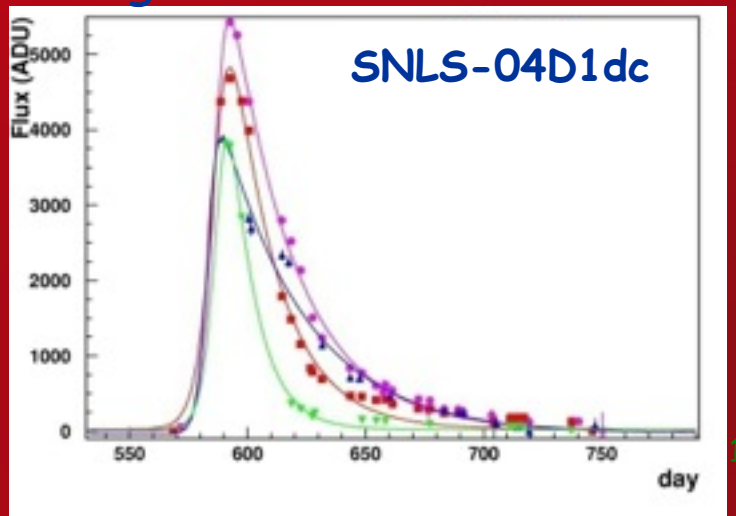
SN-like candidates → photometry → SN CC

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

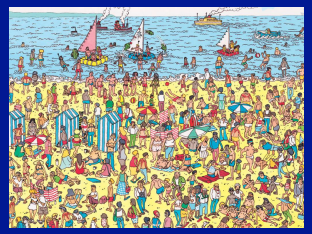
before explosion



SN light curve



Photometric detection



Transient events: Differentiate them from permanent objects

Subtraction of reference images from "current"

Preprocessing

Elixir
Preprocessing:
-Flat-fielding
-Fringe subtraction

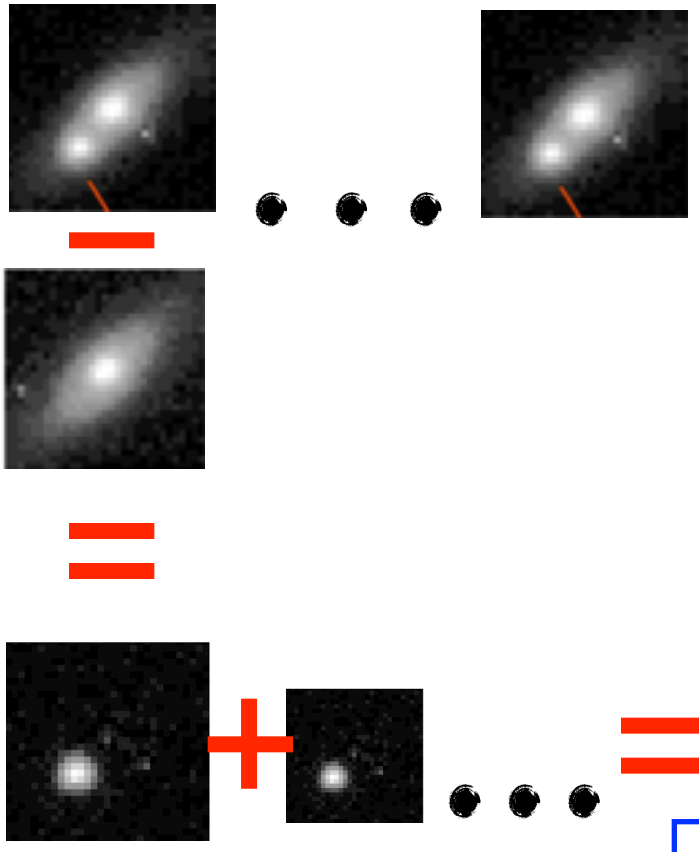
current images

reference image

Subtraction

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

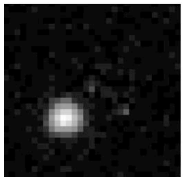
subtracted images



images on the same lunation
to increase S/N

lunation stacks

Detection of transient events (a.k.a. "Waldo's gang") in SNLS-3y



lunation stacks

4 fields @ 3-year processing

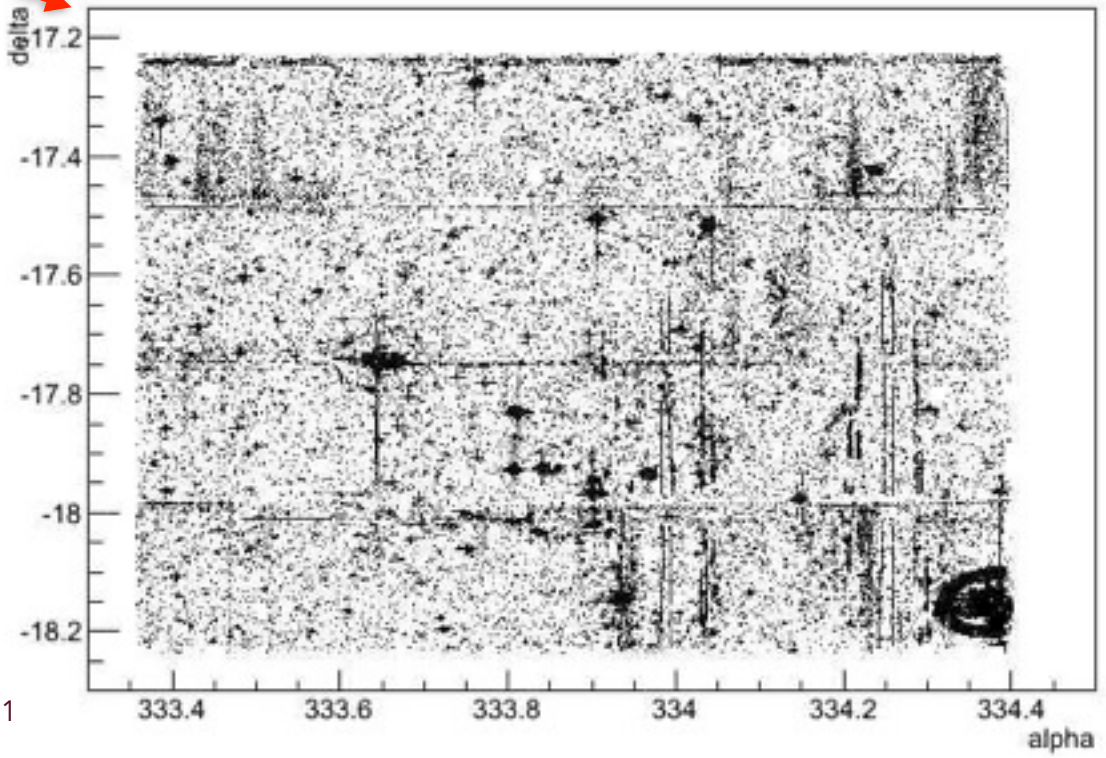
Detections: 302,987

SN-like candidates: 1,483

SN-like candidates
+ spurious
detections

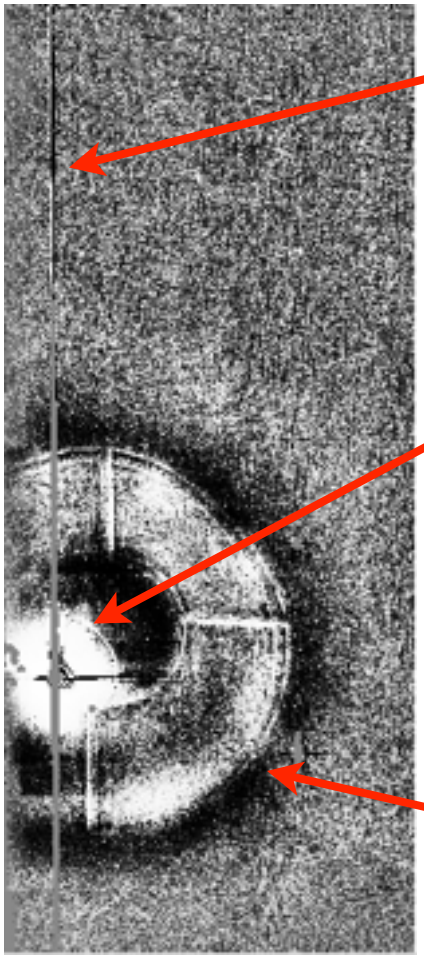
test sample: field D4 detections 90,971

Sn-like 362



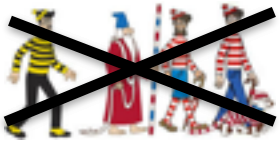
SNLS-3y photometric detection example

stack example



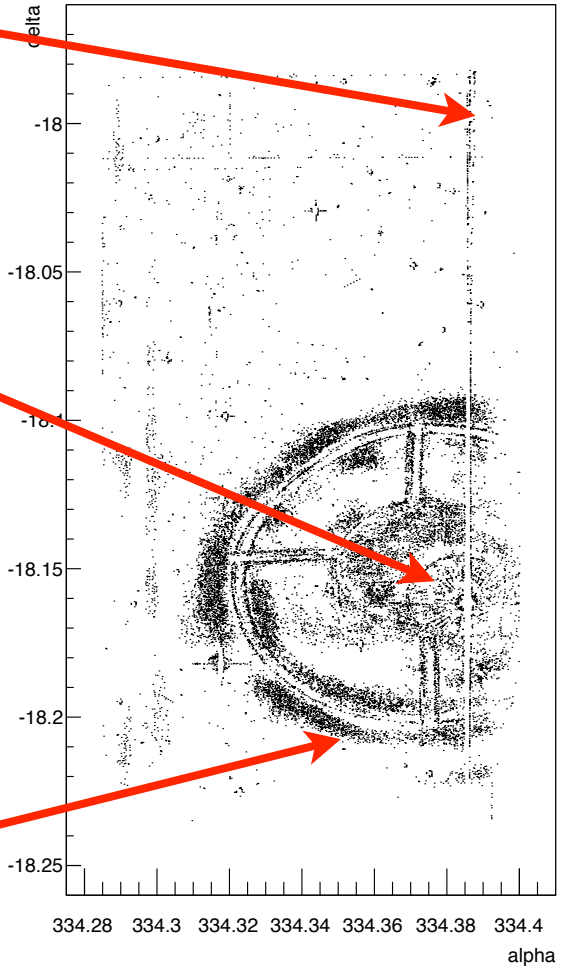
resampling and mask

saturated star



mounting

detection map



Morphological Component Analysis

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

new method to reduce spurious detections at the lunation stack level

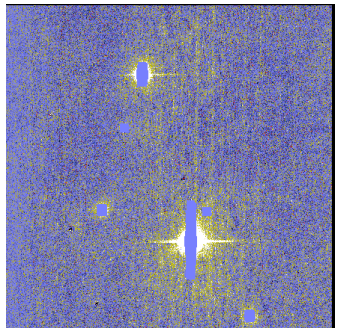
Hypothesis: a stack image can be decomposed completely in different "dictionaries"

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

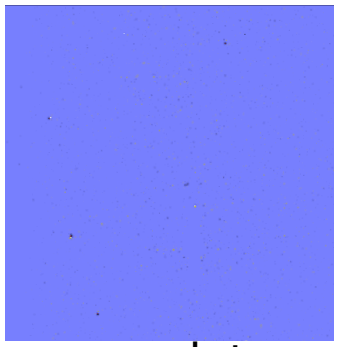
Dictionary: family of atoms that can be used to decompose a signal at different scales. (e.g. set of Sines at all frequencies)

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

Search for "**circular shaped**" signals in the second or third **scales**

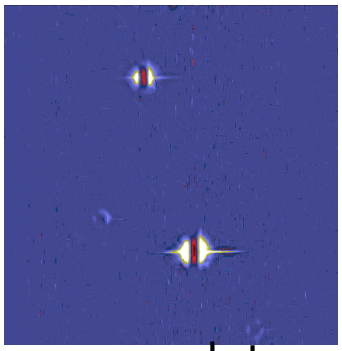


original image

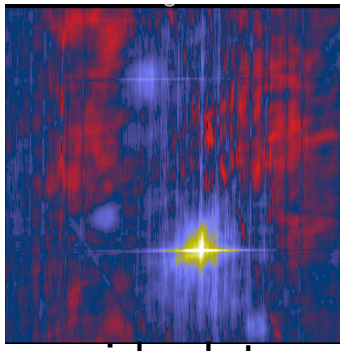


wavelets

modified starlet bi-orthogonal



curvelet



ridgelet

1. First treatment

We adapted a code from Starck et al. that uses morphological decomposition at different scales to reduce spurious signals. And performed an optimisation of the code parameters.

J.L. Starck, F. Murtagh, and J. Fadili, Sparse Image and Signal Processing: Wavelets, Curvelets, Morphological Diversity , Cambridge University Press, Cambridge (GB), 2010.

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

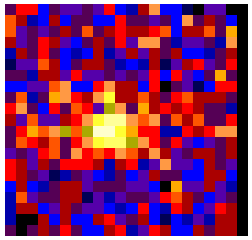
-curvelet

-ridgelet

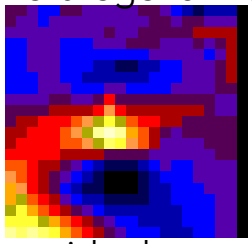
Noise map

-residuals

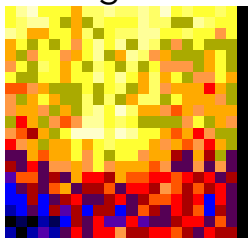
original stack



bi-orthogonal wt



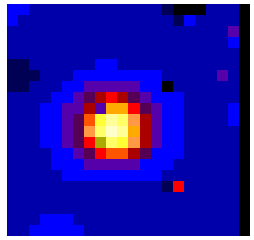
ridgelet



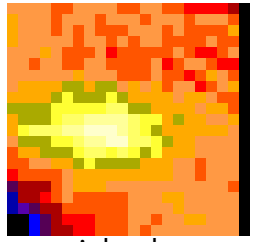
SN

D4-16-95

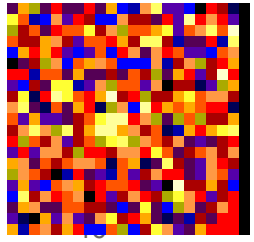
modified starlet



curvelet



residuals



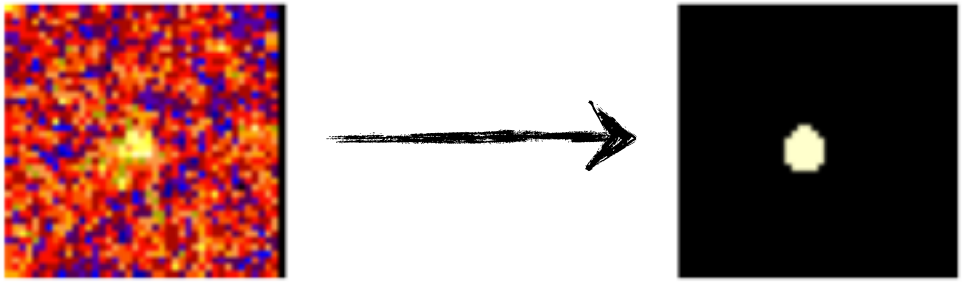
2. Second treatment

Accounting for non stationary and non gaussian noise

- takes advantage once again of **morphological information** with wavelets only (first treatment decomposition is not perfect)
- supports **non stationary noise**
- no background in output image

original stack

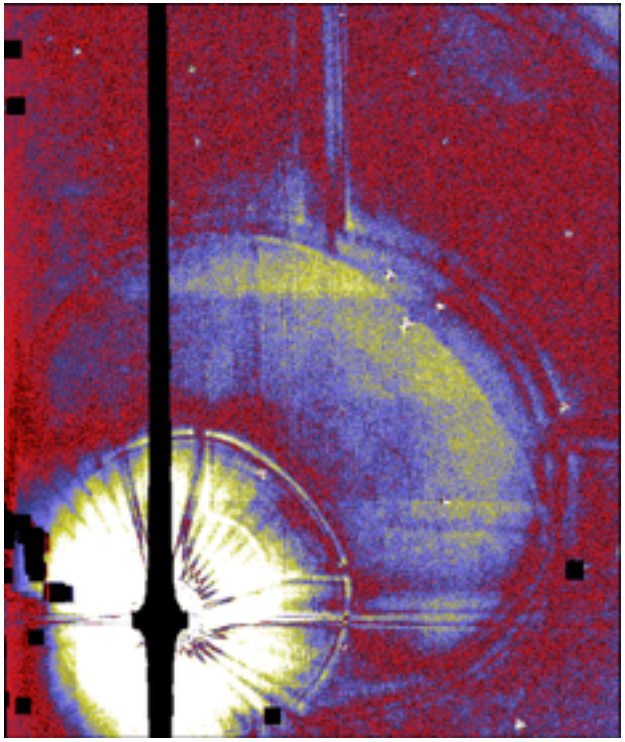
snls_detect output



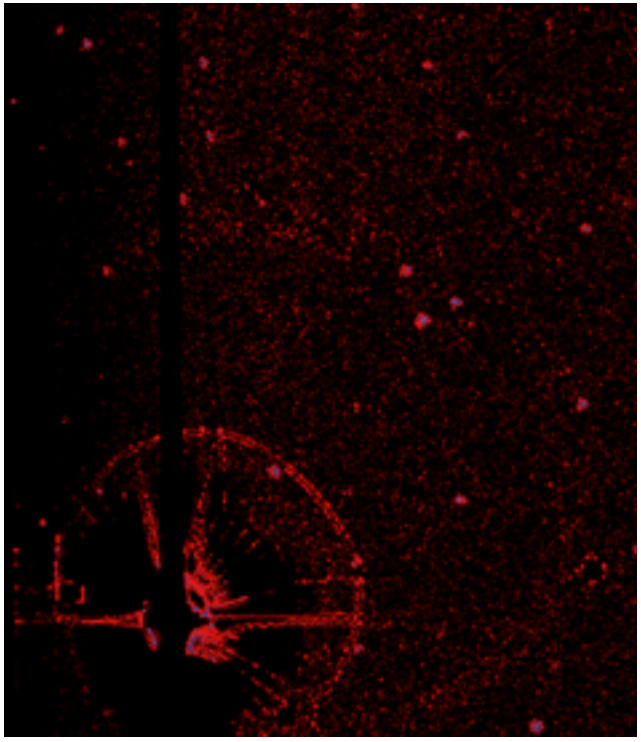
All objects output by my second treatment are candidates

Example, stack cleaning

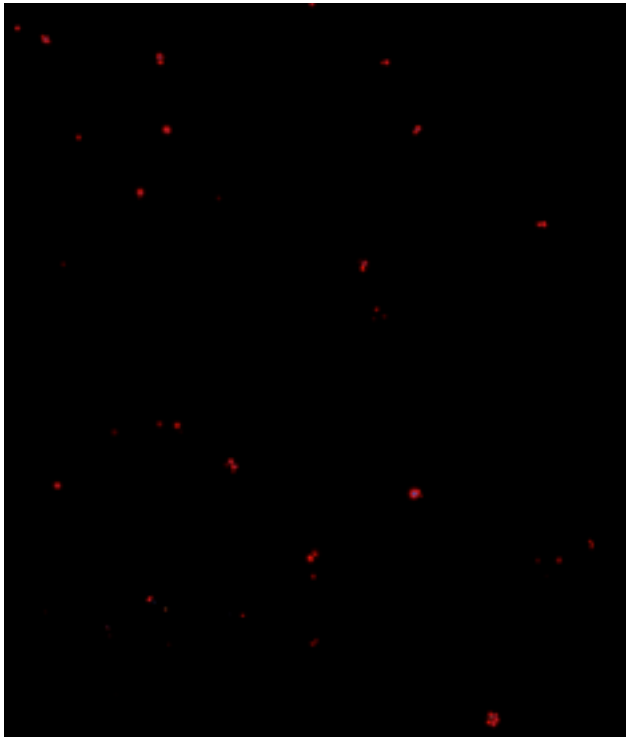
D4 CCD 00 RUN 10



original stack tile



+ first treatment



+ second treatment

detections on ccd 00 and run 10:

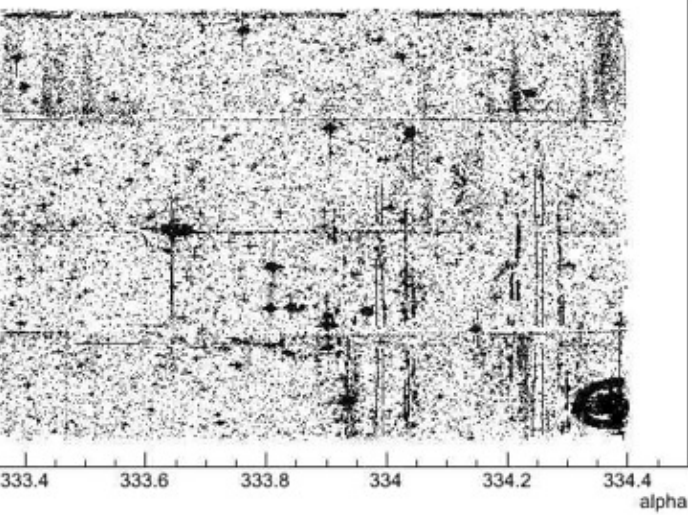
1597

detections on ccd 00 and run 10:

452

SNLS-3y after cleaning

? Efficiency detecting transient events on SNLS 3



test sample: D4 **90,971**

test sample **after** treatment:

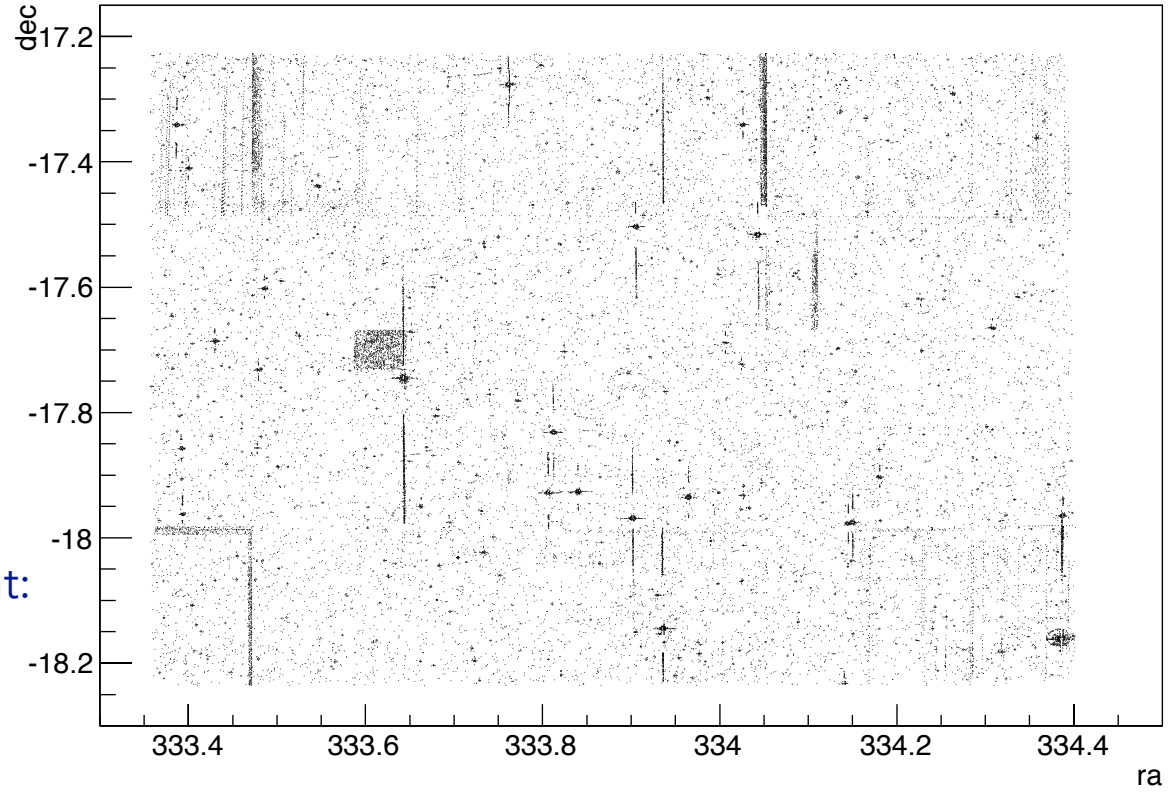
D4 **23,810**

✓ Efficiency detecting transient events on SNLS 3

Almost factor 4 reduction!

with loss of SN-like events of less than 6%

mostly very faint events not suitable for future cosmological analysis



SNIa MC studies

? Efficiency detecting SNIa?

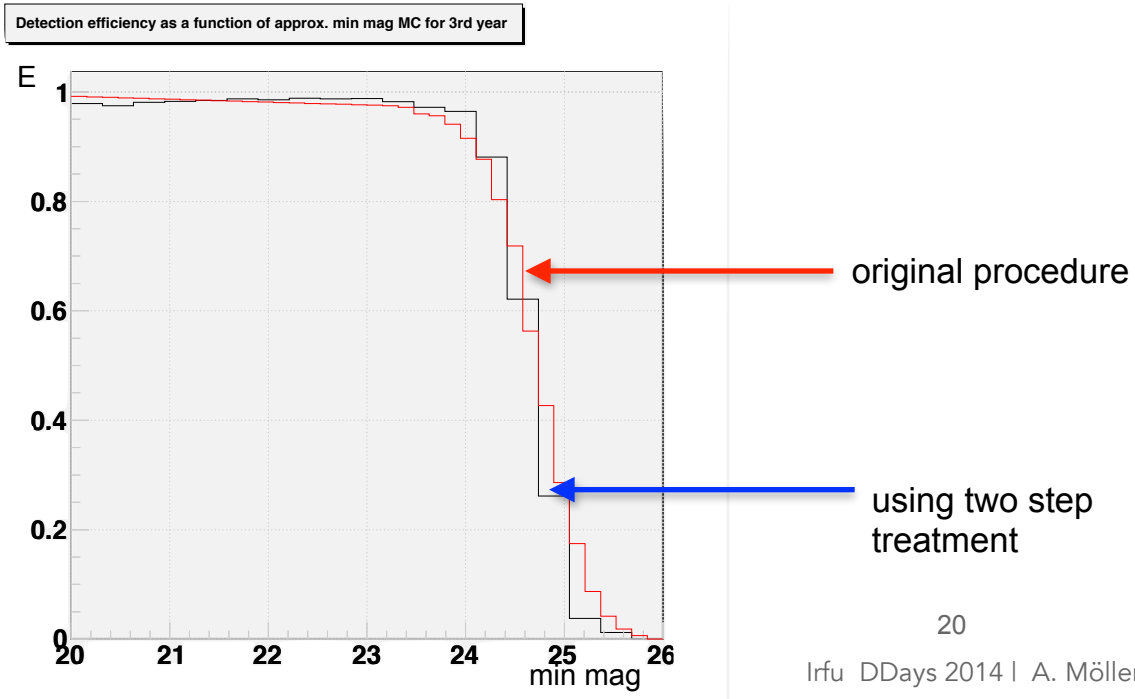
? Good coordinate resolution?

until now, **SNLS 3** studies: efficiency detecting transient events on real data

SNIa MC using real survey images:

- Larger statistics
- Coordinates of the SNIa are known (we can study coordinate resolution)
- Whole cleaning treatment applied.

✓ **Efficiency** detecting SNIa?



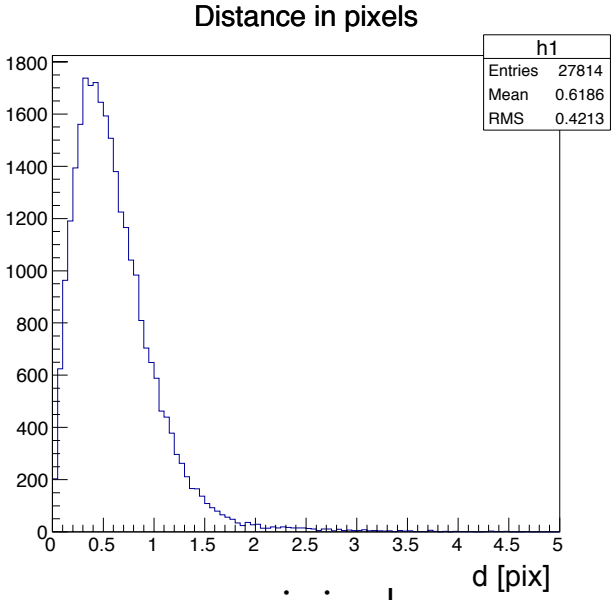
SNIa MC studies

? Efficiency detecting SNIa?

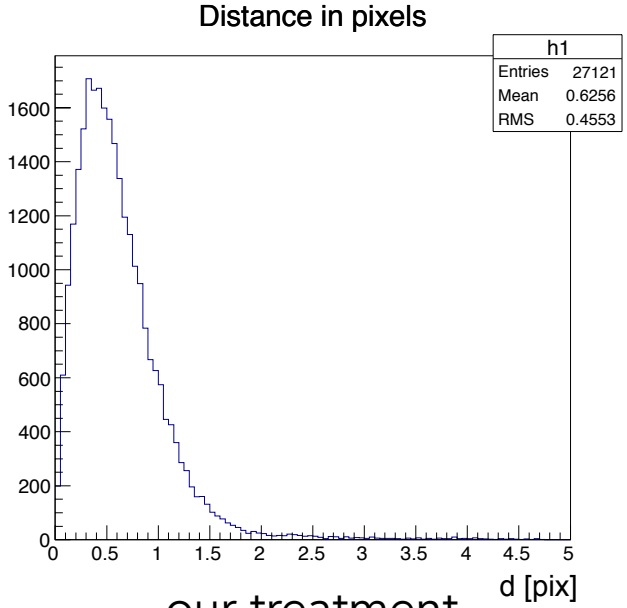
? Good coordinate resolution

Coordinate reconstruction:

- Slight degradation from original to new procedure.
  - Distance RMS difference 0.03 pixels (0.006")
  - Magnitude bias increased by 2 milimag



original

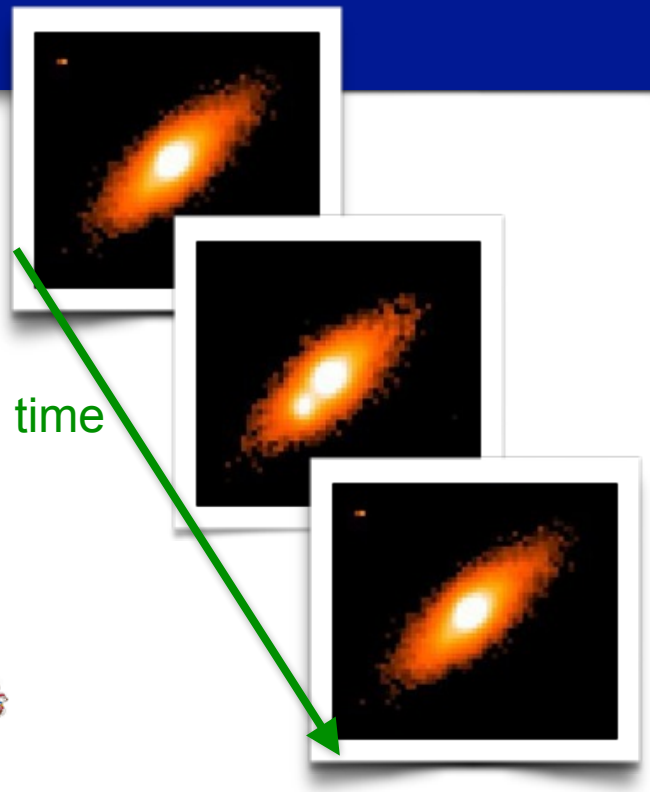


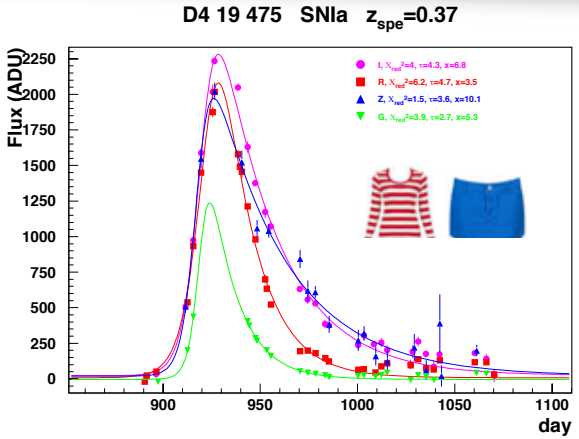
our treatment

✓ Good **coordinate** resolution

My **BIG** questions

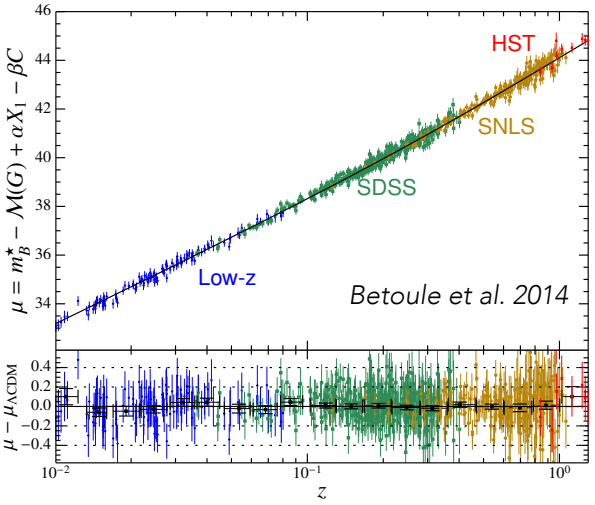
Where is Waldo?
(where are my SNIa?)





✓ Efficiency
- detecting
- detecting

✓ Good coordinate resolution



? Efficiently identifying SNIa only from photometry

? Doing cosmology with SNIa using photometric redshift:
Hubble diagram->Measuring the expansion of the universe->Equation of state of Dark Energy

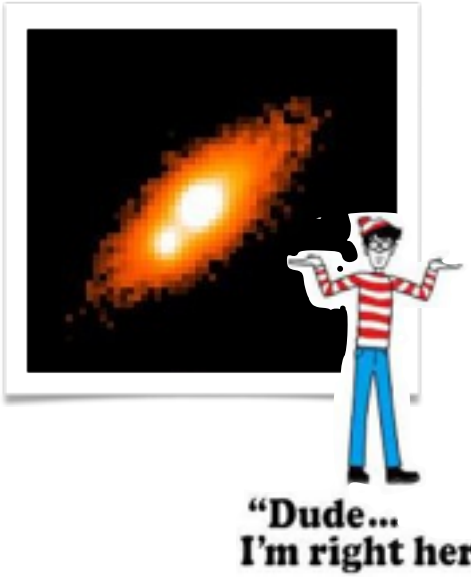
Summary and forecast

SNLS 5

- Ongoing processing
- Catalog of transient event candidates:
  - Before treatment : 575,857
  - After treatment : 142,484

- **Next:**
  - Selecting type Ia SN events with:
    - host photometric redshift (SNLS 3)
    - SN photometric redshift

  - Hubble diagrams for these



Future publication of this work…