SNIa detection and classification in the SNLS deferred photometric analysis

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*partially based on
arXiv:1501.02110


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
  - more measurements
  - more precise measurements

this presentation:

**the improvements on the SNLS deferred photometric pipeline**

\[ JLA + \text{CMB} + \text{BAO} \, w = -1.027 \pm 0.055 \]

(\text{using Planck 2013})
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 SNLS approach: e.g. Astier et al. 2005

Transient events

Photometry
Real-time detection of SN like events

Spectroscopy
~6,000 SN-like

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 SNLS approach

- Transient events
- Photometry
- Real-time detection of SN like events
- Spectroscopy
- ~6,000 SN-like

Saclay SNLS group: photometric approach

- Transient events
- Photometry

SN-like candidates
- 1,483 candidates

SN Classification
- SNe Ia
- SN CC

Photometry

Transitient detection

Subtraction of reference images from “current”

- current images
- reference image
- subtracted images

images on the same lunation to increase S/N

lunation stacks
Transient detection map

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

arXiv:1501.02110
Artifacts that yield spurious detections

- Stack example
- Detection map
- Resampling and mask
- Saturated star
- Mounting
Common defects-artifacts

- Bright star, mask
- Mounting shadow
- Resampling
- Dipoles

"Large" scale

"Small" scale
Hypothesis: a stack image can be decomposed completely in different “dictionaries”
Step 1: removal main artifacts

Algorithm by Starck et. al
- Starlet, wavelet, ridgelet, curvelet dictionaries
- Iterative
- Noise assumed stationary and gaussian

Step
before
after
Starlet + residuals
Step 2: non-stationary noise

- Step 1: removal of main artifacts

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

Original stack after two step SNIIa

After two step time
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
Monte Carlo artificial images in the i filter for one year survey.

<table>
<thead>
<tr>
<th>Stack</th>
<th>Old procedure</th>
<th>New procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>coordinate</td>
<td>coordinate</td>
</tr>
<tr>
<td></td>
<td>resolution</td>
<td>resolution</td>
</tr>
<tr>
<td></td>
<td>bias</td>
<td>bias</td>
</tr>
<tr>
<td>1-year</td>
<td>±0.002</td>
<td>±0.002</td>
</tr>
<tr>
<td>3-year</td>
<td>0.725</td>
<td>0.698</td>
</tr>
<tr>
<td>5-year</td>
<td>0.741</td>
<td>0.726</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Field</th>
<th>Old procedure</th>
<th>New procedure</th>
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</thead>
<tbody>
<tr>
<td></td>
<td># detected</td>
<td># SN-like</td>
</tr>
<tr>
<td>All</td>
<td>302,987</td>
<td>1,483</td>
</tr>
</tbody>
</table>
**Transient detection**

- Transient events

**Photometric analysis**

- SN-like candidates
- SN-like variation
- Star rejection
- Quality cuts on light curves

**SN Classification**

- SNe Ia
- SN CC

**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 → SN-like candidates

SN Classification

extract features

(i) light curve fitter
   a. SALT2 Guy et al. 2007
   b. SN general

(ii) redshift

classify

Transient detection

improved
(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

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 phot CC = 13
SN photometric classification

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

<table>
<thead>
<tr>
<th>purity SNe Ia</th>
<th>contamination bad redshift SNe Ia</th>
<th>contamination core-collapse</th>
<th>efficiency SNIa</th>
</tr>
</thead>
<tbody>
<tr>
<td>95.82 ± 0.08%</td>
<td>0.29 ± 0.01%</td>
<td>3.88 ± 0.08%</td>
<td>32.2 ± 0.8%</td>
</tr>
</tbody>
</table>
Transient detection

SN-like candidates

SN Classification

Improved

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.

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%.

100% photometric SNe Ia sample.

near future: to be applied with SNLS5 data

Stay tuned!
Backup
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”

Images on the same lunation to increase S/N
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.

original stack

after two step

SNIIa

time
Improved detection map