# LSST DM STACK image difference on CFHTLS images

## Transient search

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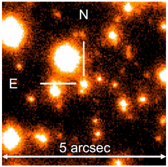
# Outline

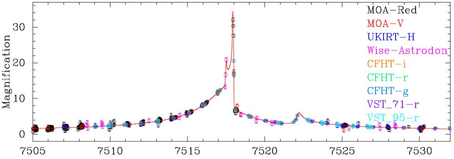
# Introduction

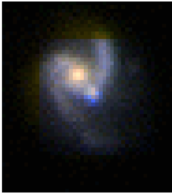


## Introduction

Transients are of interest for various science topics : variable star ,quasars, microlensing, cosmology with supernovae, moving objects ...



# The DM Stack image difference



## The DM Stack image difference

The transients have to be discovered then followed up.
For LSST will provide an alert system for transient.
The discovery is made through image difference, implemented in the DM stack.
Image difference can have other application, including differential photometry for light curve measurement

# The DM Stack image difference implementation



## The DM Stack image difference implementation

Basics for image differencing is solving astrometric match and PSF match beetween two images from different epochs.
For PSF matching, the Alard lupton algorithm is implemented.
The kernel to match the PSF between the two images together (and the differential background b) is found by solving :

$$[Ref \otimes Kernel](x, y) + b(x, y) = I(x, y)$$

# The DM Stack image difference implementation



## The DM Stack image difference implementation

$$[Ref \otimes Kernel](x, y) + b(x, y) = I(x, y)$$

The problem is linearised using a basis of function to project the kernel. The solution of the fit are the parameters of the functions. For the basis functions Ki(u, v), it use a set of N Gaussians multiply by polynomials.

Detection on the difference image occurs through convolution with the new image's PSF either with pre-filtering or a more classical post convolution.

A last (new) feature (not covered in this presentation) is an image difference decorrelation (see B.Zackay talk for the concept)

# The DM Stack image difference on simulation



## Test of performance has benn performed on simulated images (Becker 2013, unpublished)

Simulation is a field of basic stars ($19 < r < 21$) :

- identical spectral energy distributions
- no variability, no proper motion, and no parallax
- no instrumental effect
- no chromatic effects

variation = seeing and exposure time + registration error

# The DM Stack image difference on simulation



## Test of performance on simulated images

The difference image source are called DiaSources
They are measured using a psf-weighted flux photometry
Differences have been performed for different sets of paremeter to construct the kernel (kernel base functions, spatial variation)

# The DM Stack image difference on simulation



## Fake rate compatible with noise expectation

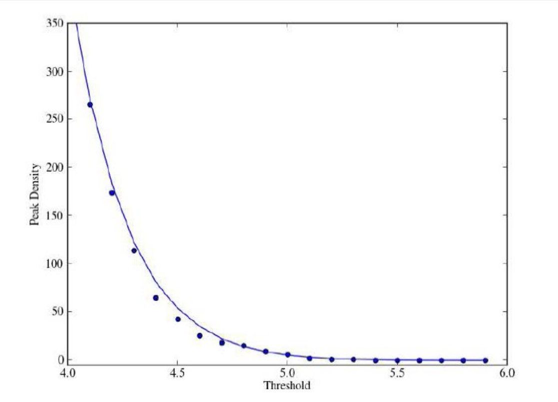



Figure : A comparison of the predicted number of random peaks (solid line) detected in an image, as a function of significance, with

# Image difference of the CFHTLS deep



## The CFHTLS deep field

4 fields of 1 square degree, observed during five years, in 5 bands.
Type IA supernovae have search for and measured using rolling cadence strategy by the SNLS Collaboration

# processing of CFHTLS deep field



## Using and adpating the DM stack

- Stack version build locally (lsssw) and frezzed for monthes (year..)
- package modified to make changes to that version
- run on multicore(28) machine @Marseille + some test @CCIN2P3

## Modification to the stack

- Use debugging from Dominique B (always first!) to handle CFHT obs
- packages modified to handle image difference properly : obs_cfht, pipe_task, ip_diffim

# processing of CFHT deep field



## The data processed for image difference study on this presentation

- 1 field : D3
- 1 filter : r
- 2 seasons : 2005 for reference image, 2006 for discovery/follow up

## The image difference procedure

- 5 visits per day, test on single visit or coadded per day
- difference made at patch level on both reference and new image.

# processing of CFHT deep field



## The pipeline used

- processCCd starting from the CFHT reduced images.
- coaddition made without joint astrometry
- image difference at patch level
- DiaSource detection and characterization
- Lightcurve building from multimatch

## Some goals of this reprocessing

- Check the results out of the stack
- Explore the residual artifacts and possible improvment
- Compare with published SN results
- exhaustive CFHT transient study

# Diasource characterization



## Diasources artifacts

Figure : Artifacts found

## Diasources artifacts

Diasource are measure as dipole objects, the flux in the positive and negative part is measured separatly

# Diasource characterization



## Diasources artifacts

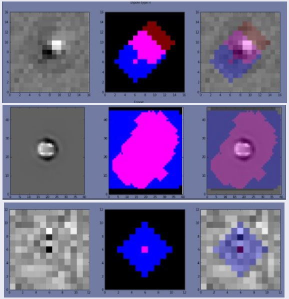


Figure : Three different types of artifacts

# Diasource characterization



## Diasources characterization metrics

- Dipole balance (positive flux lobe vs negative one)
- Overlap beetween the two footprints
- Second moments

# Diasource characterization



## Results of labelisation (on going work)

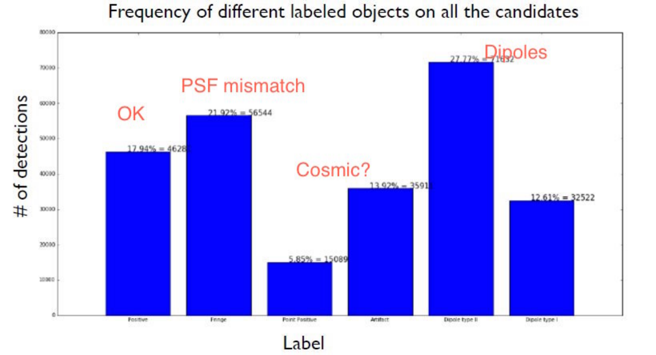



Figure : labels populations

# Diasource characterization



## Results of labelisation (on going work)

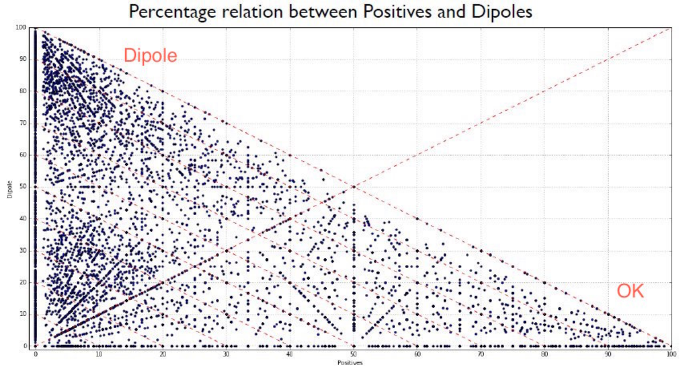



Figure : percentage of dipole vs percentage of good detection on lightcurve candidate

# Study of subtraction parameters



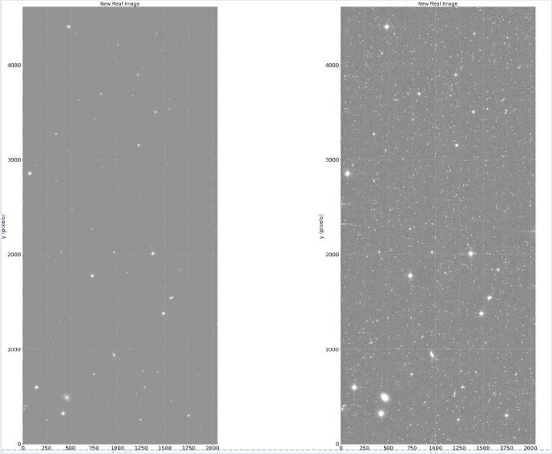
## Parameters

- Spatial kernel Order (SKO)
- Cell size
- number of gaussianon candidates
- ...

# study of subtraction parameters



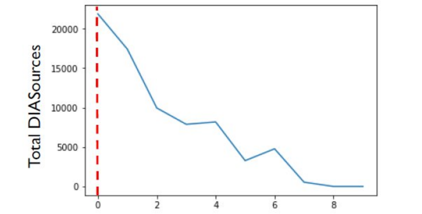
## Simulation of fake transient on top of real image



# Study of subtraction parameters (on going work)



## results



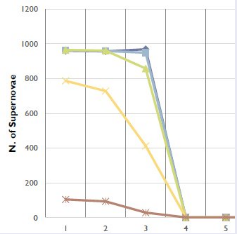




Figure : Fake reduction and efficiency as function of Spatial kernel

# Results on transient candidate search



## Numbers of the processing

- D3. 2 season, filter r
- 23 days + 15 days (reference)
- 800 000 detections ie : 20 000 detections / square deg (threshold = ? 3 sigma of noise ?)
- 55166 lightcurves (with *nday* >= 3))
- about 8h on a 28 core machine

## Result on reference supernova sample

17 SN expected from SNLS (spectral identification): 17 found

# Photometry for supernova candidate



## SNLS/JLA photometry

The flux measurement is a PSF photometry with a background galaxy model fit on an image serie.
The parameters are the galaxy model, the fixed position and varying flux of the SN.

## Stack Photometry (real time)

The flux measurement used is aperture photometry (4.5 and 6 pix) performed on image difference (on diasource) at the position of the diasource.

## Calibration

NO Calibration
SNLS and DM stack Lightcitve are normalised

# diasource photometry on supernova candidate



## low z SN : 06D3el : z=0.52

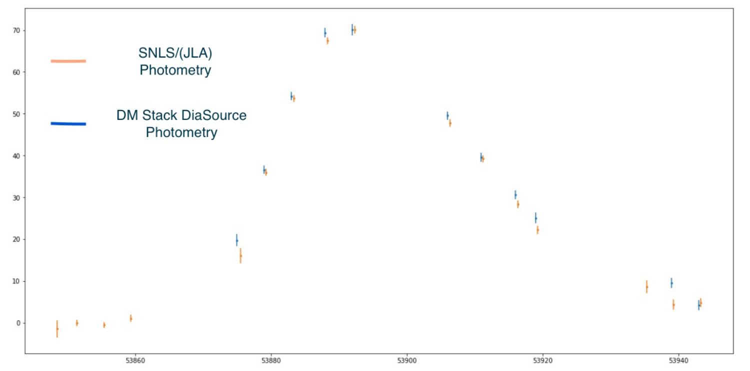



Figure : low z SN

# diasource photometry on supernova candidate



## medium z SN : 06D3gh : z=0.72

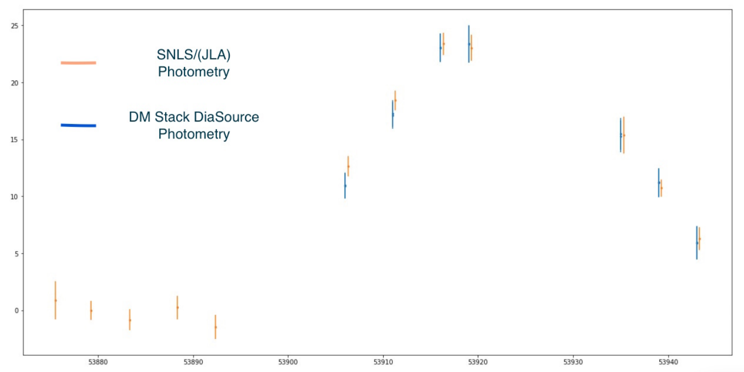



Figure : medium z SN

# diasource photometry on supernova candidate



## high z SN : 06D3en : z=1.06

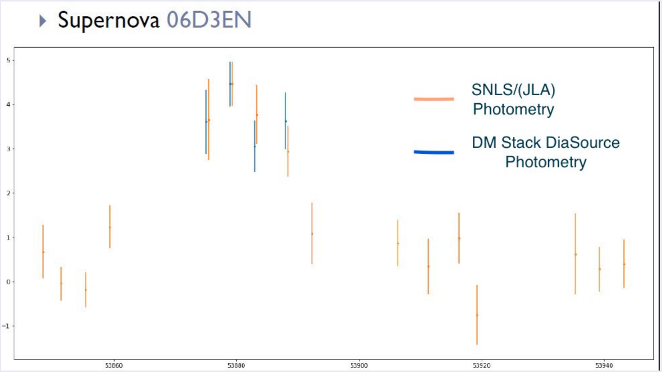



Figure : high z SN

# diasource photometry on supernova candidate



## sensitivy

Faintest published SN of SNLS (r mag detected = 25)

Sent to specto because i and z mag = 23.5

## high z SN

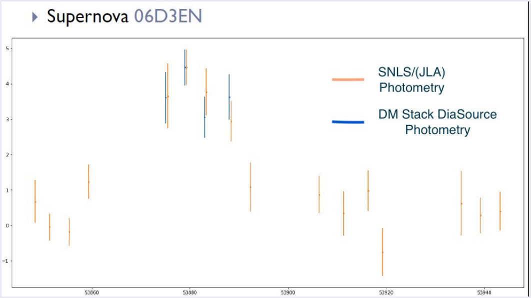



Figure : high z SN

# Conclusion and outlook



## Conclusion

First complete test of image subtraction on a CFHTLS deep field over a season with DM stack

Several checks on artifact under investigation

Transient search has started, validated with supernova SNLS sample.

## Outlook

Studies the transients sample and artifact labelisation

Pursue investigation on image difference photometry : forced PSF photometry on diasources

...