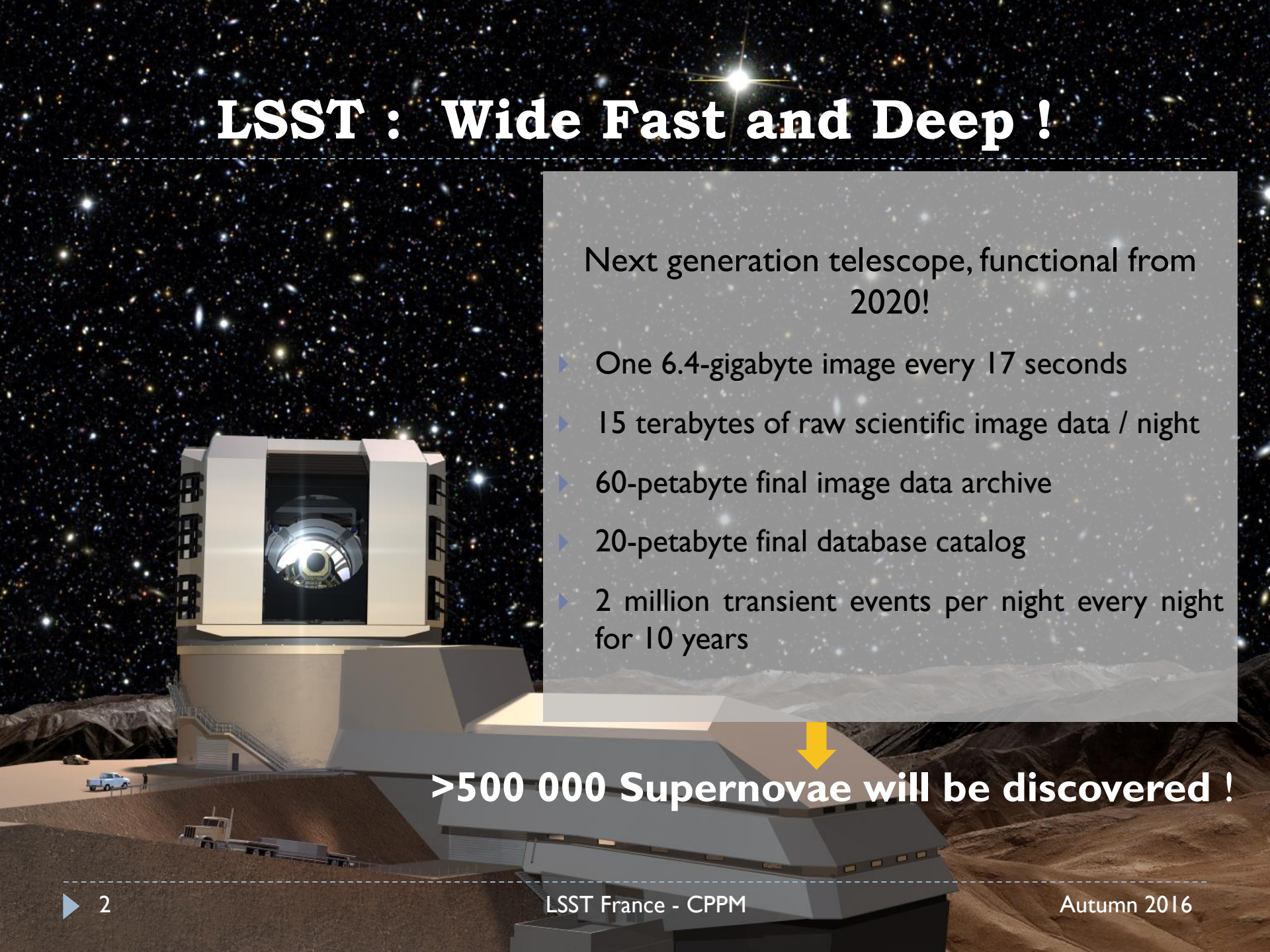
Astronomical image processing from large all-sky photometric surveys for the detection and the measurement of transients

By: Juan Pablo Reyes Gómez
Supervisors: Dominique FOUCHEZ and Marcela HERNANDEZ HOYOS

LSST : Wide Fast and Deep !



Next generation telescope, functional from 2020!

- One 6.4-gigabyte image every 17 seconds
- 15 terabytes of raw scientific image data / night
- 60-petabyte final image data archive
- 20-petabyte final database catalog
- 2 million transient events per night every night for 10 years

>500 000 Supernovae will be discovered !

Context

- **Supernovae are transients objects :**
  - Flux varying objects
  - Found by image difference method

- **LSST software framework (DM-STACK)**
  - A collection of source code in the form of a framework.
  - An application layer in Python.
  - A middleware layer in C++.
  - Provides a distributed database in qserv.

Objectives of the Thesis

- Validate and improve LSST image difference software using real CFHTLS image sample and LSST simulated images.
- Implement automatic classification methods to cope with LSST dataflow and improve the efficiency.
- Develop a scalable solution that includes Big Data management strategies.

Pipeline implementation

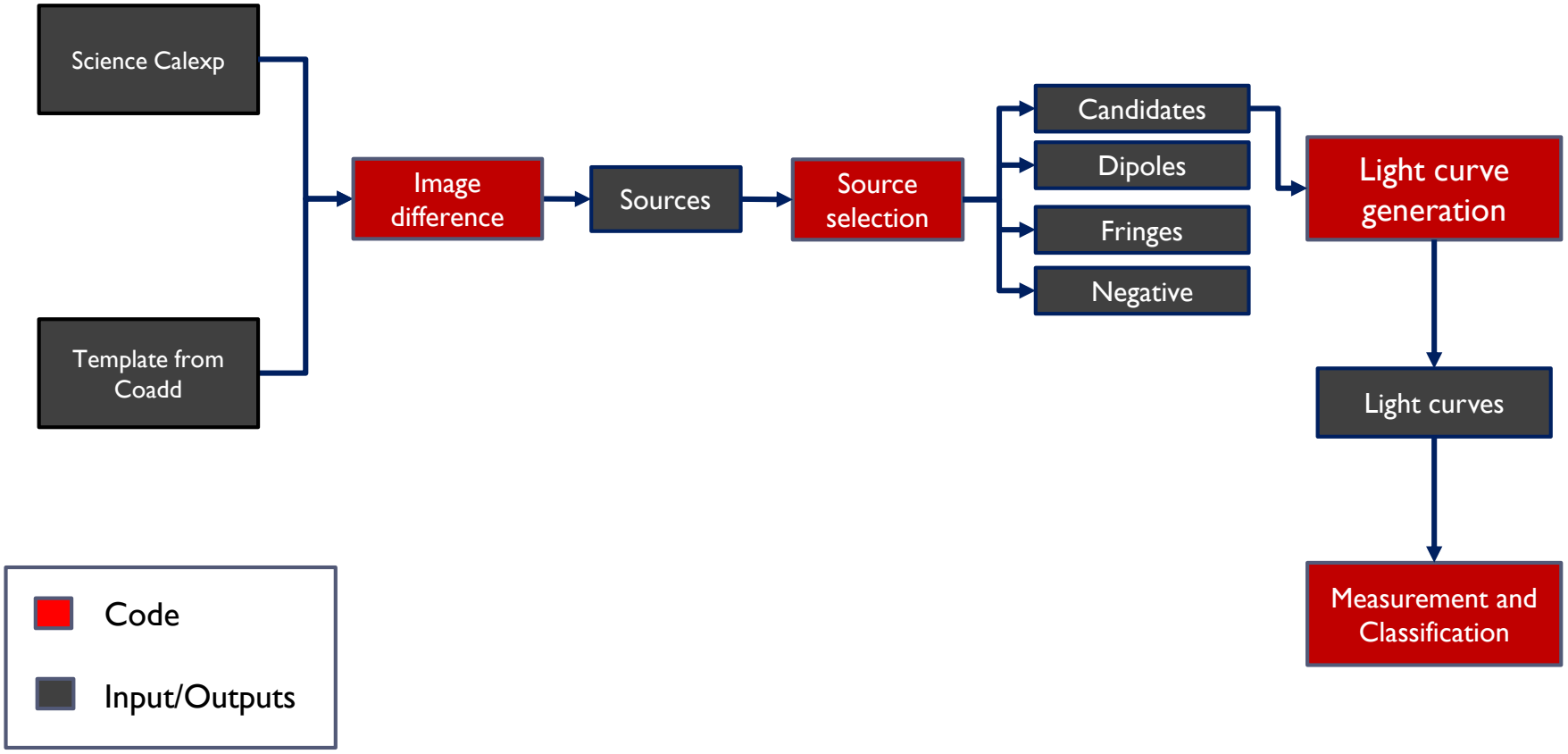
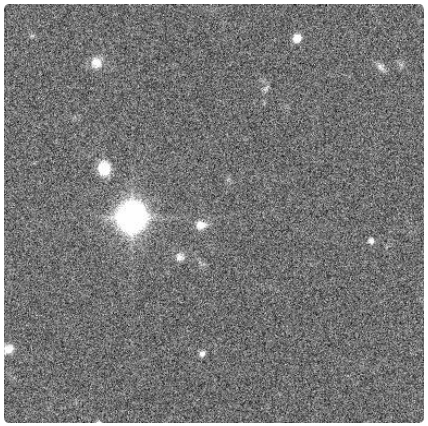


Image difference: Alard-Lupton PSF-matching subtraction

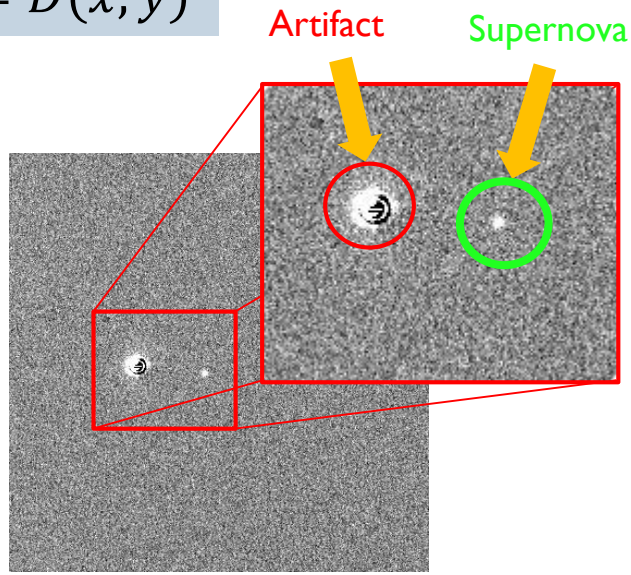
- $T(x,y)$ is convolved with $K(x,y,u,v)$ to PSF-match it to $S(x,y)$.
- The PSF-matched $T(x,y)$ is finally subtracted to $S(x,y)$ pixel to pixel.
- Transients and variable objects are detected in D(x,y)

$$S(x,y) - T(x,y) \otimes K(x,y,u,v) = D(x,y)$$



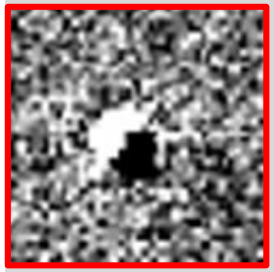
Science Image $S(x,y)$

Template Image $T(x,y)$



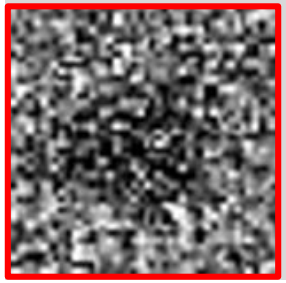
Difference Image $D(x,y)$

Source selection: Artifact classification



Dipoles: astrometry and alignment solution inaccuracies.

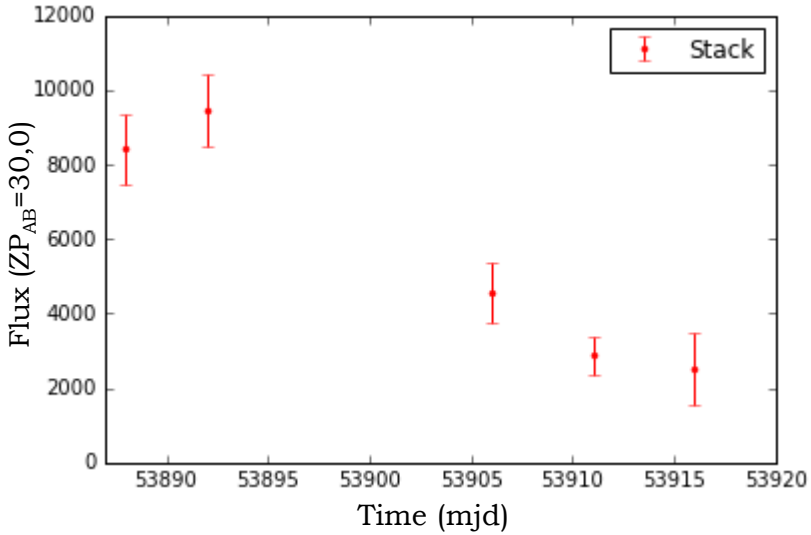
Fringes: kernel mismatch residuals.



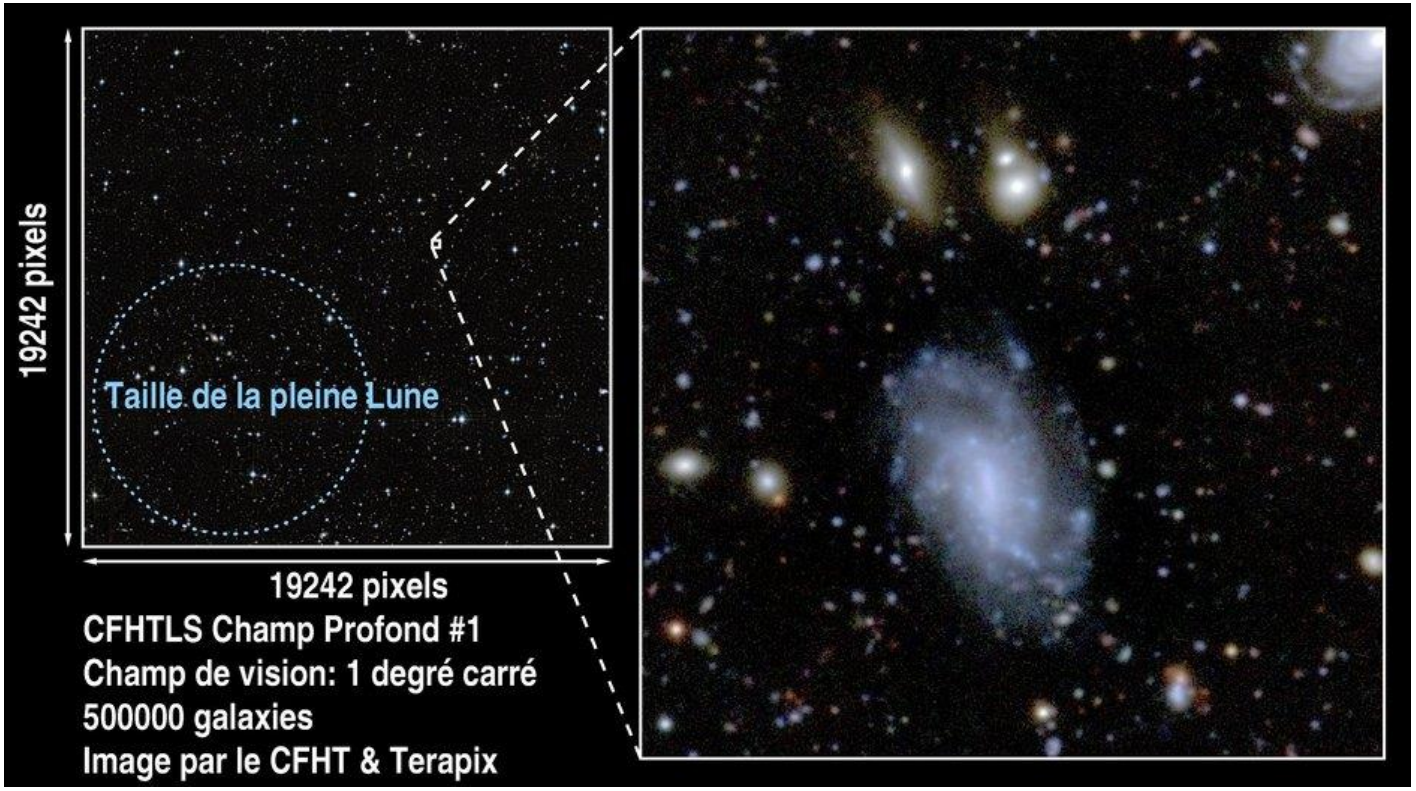
Negative detections: possible transients or artifacts in template image.

Light curve generation

- Good detections are selected after artifact identification.
- Light curves : candidates with N good detections at same sky position.



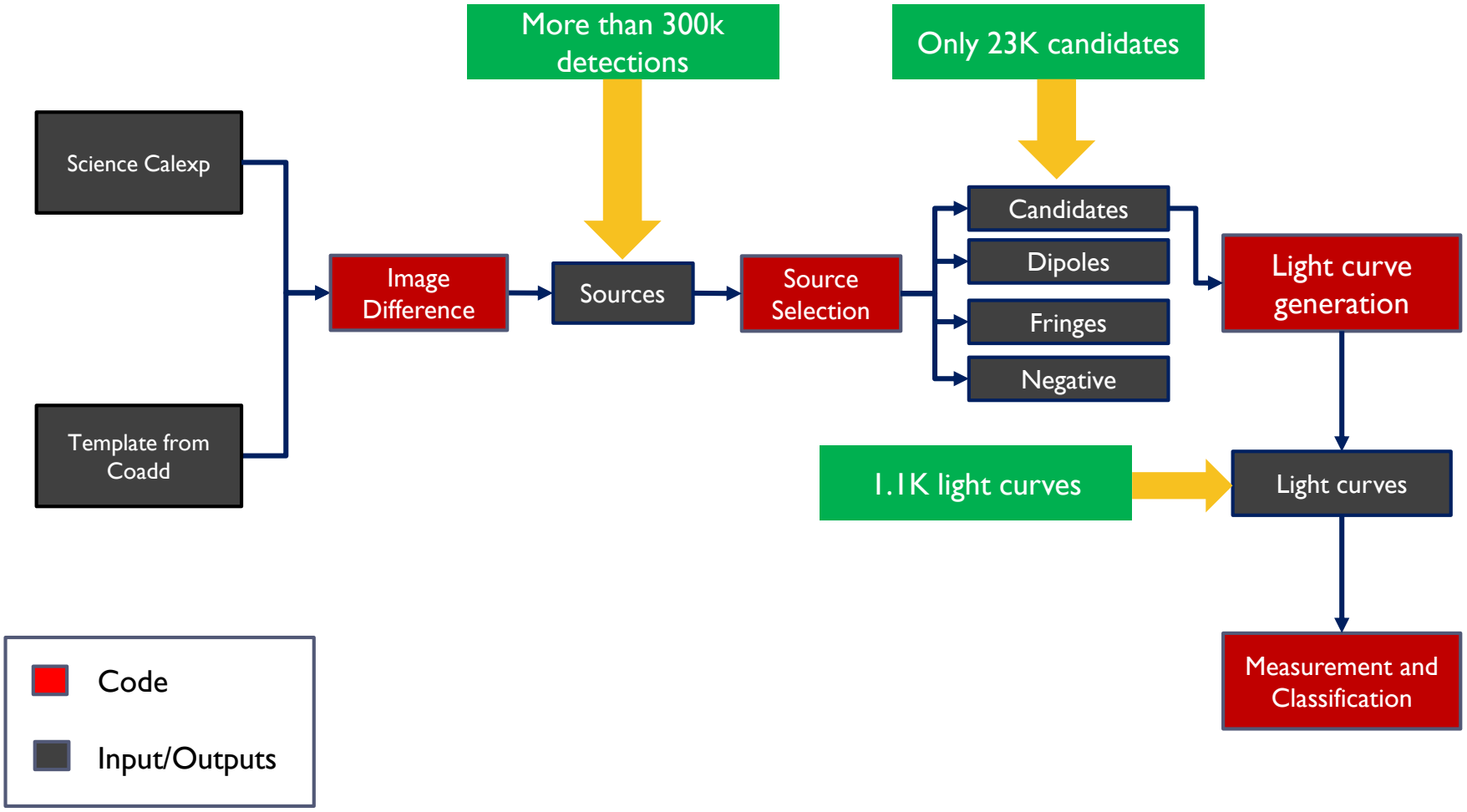
Measurement and Classification: Validation with CFHTLS/SNLS data



- *CFHT-LS data. :*

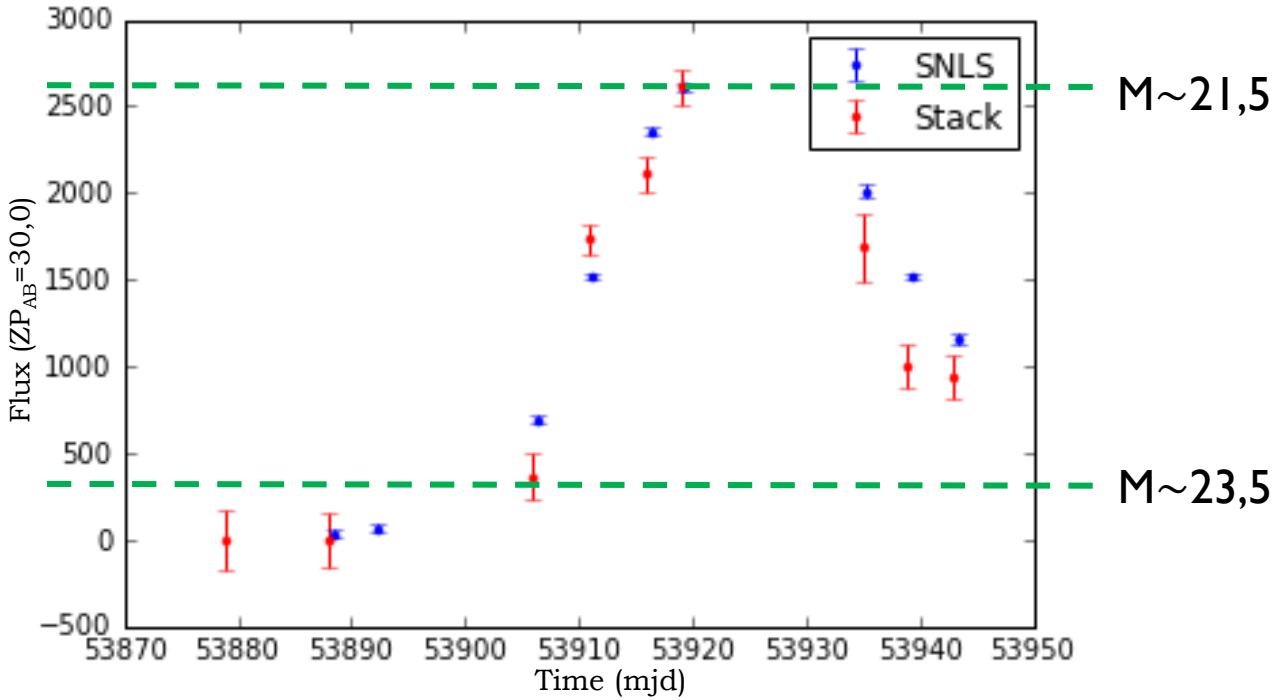
  1 season.*1* deg^2.*36* CCDs. *5* visits per night. 17 Type IA SN

Results:
Pipeline performance on CFHT images



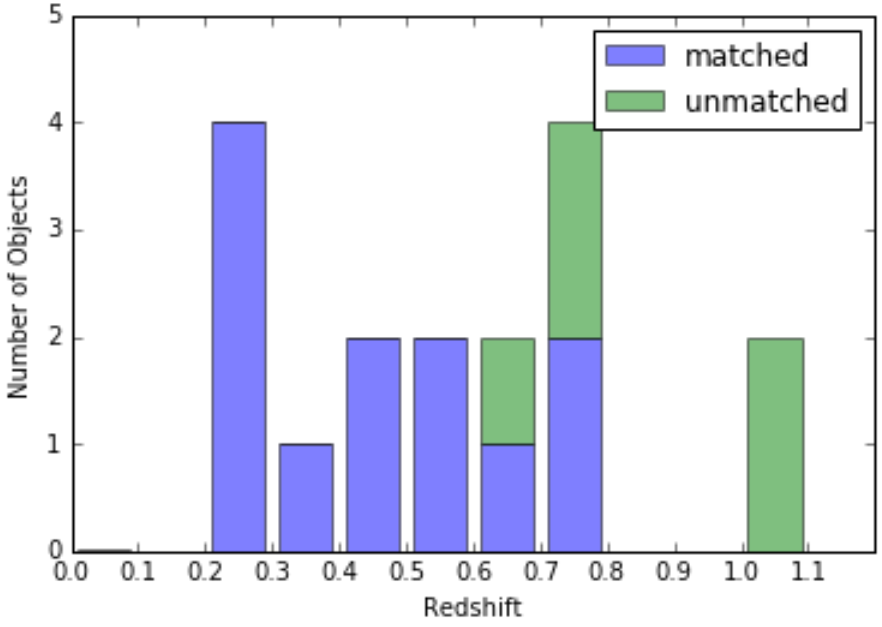
Results: Validation

- Comparison with relative flux in Stack (Difference photometry and Shallow reference exposure)
- Limit flux magnitude is approximately *23,5*.



Results:
Detection efficiency

- *70%* of Supernovae detected by SNLS were found.
- All Supernovae detected up to a redshift ~ 0.7 *(*Below *M=23,5)*
- Next pipeline iteration will correct this.



Conclusions & Perspectives

- Supernovae are detected on CFHT-LS data with Stack up to a $M \sim 23.5$
- *1148* transient candidates to be closely evaluated.
- Light curves from Stack are compatible with SNLS publications.

- Improve overall efficiency and accuracy of the algorithm.
- Use Machine Learning for candidates classification.
- Measure efficiency on simulated images.
- Article with all data processed.