

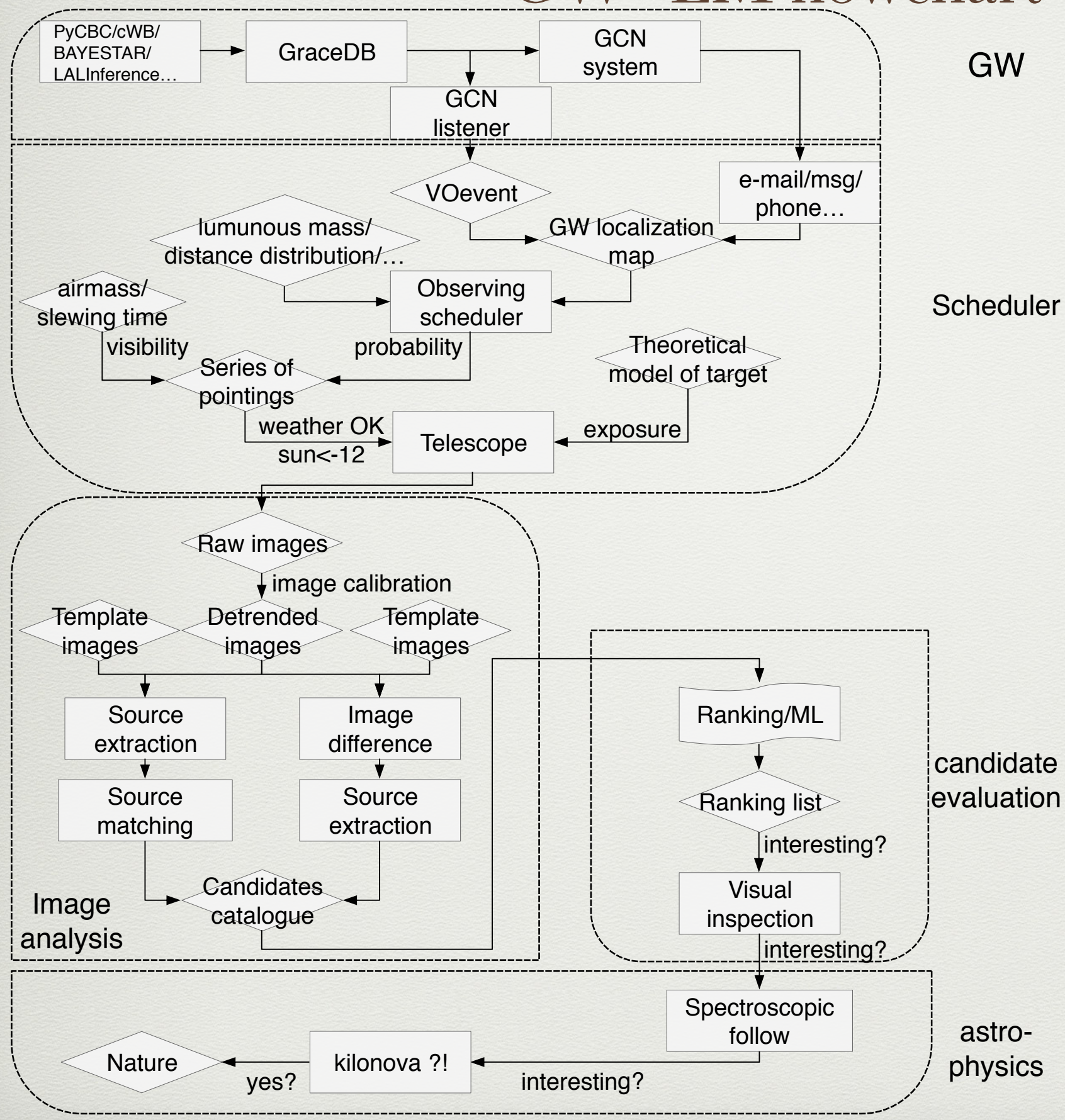
MACHINE LEARNING IMPLEMENTATION IN THE MULTI- MESSENGER SEARCH OF GRAVITATIONAL WAVE SOURCES

Sheng Yang (OAPD, INAF)

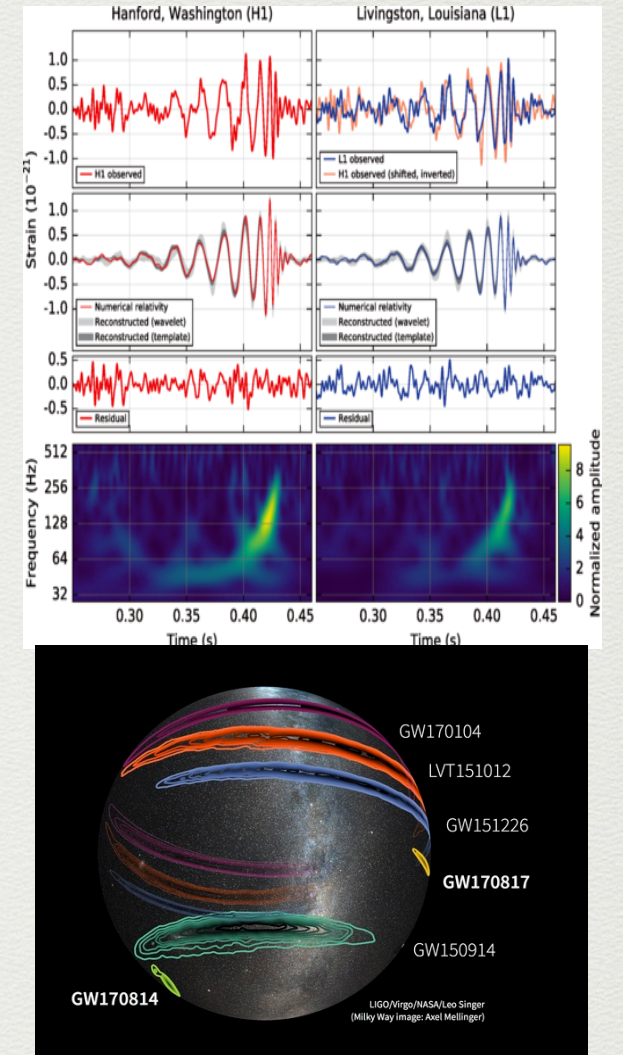
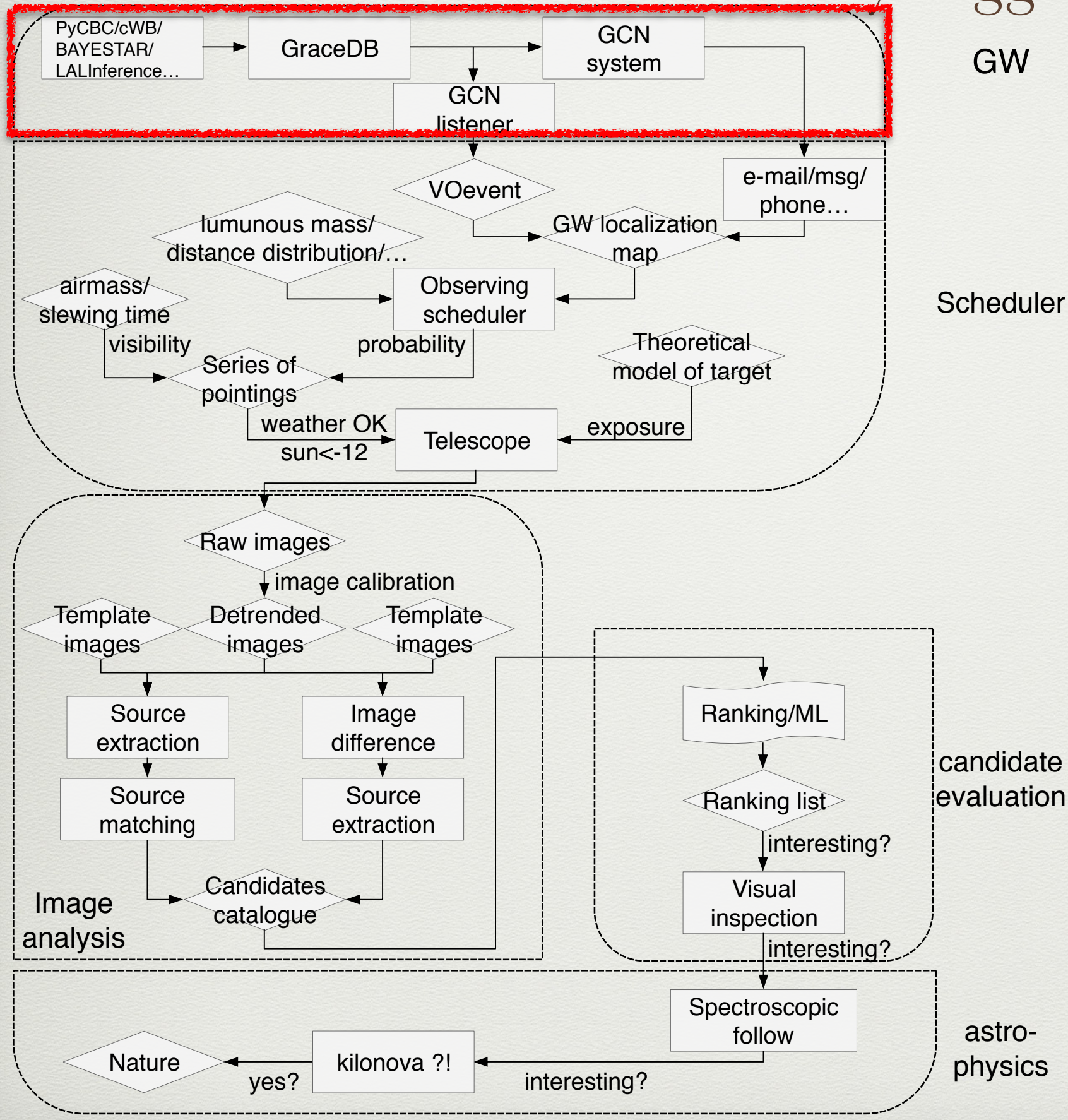
2019/6/19@Roma

INAF Science Archives & the Big Data Challenge

GW+EM flowchart

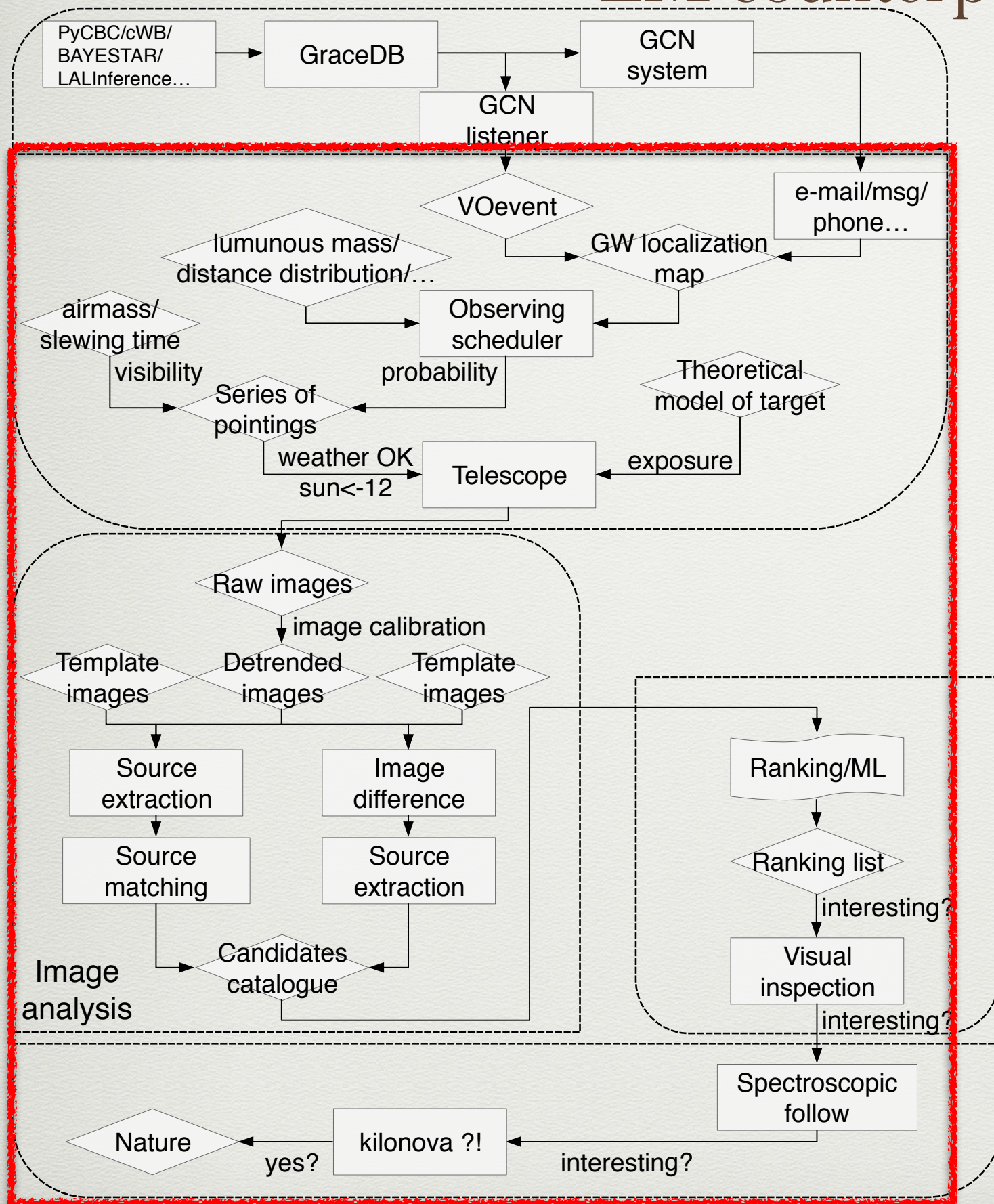


GW: low latency triggers



analytic GW analysis: ~hours

EM counterpart



GW

Scheduler

MMA sources for LIGO/VIRGO:

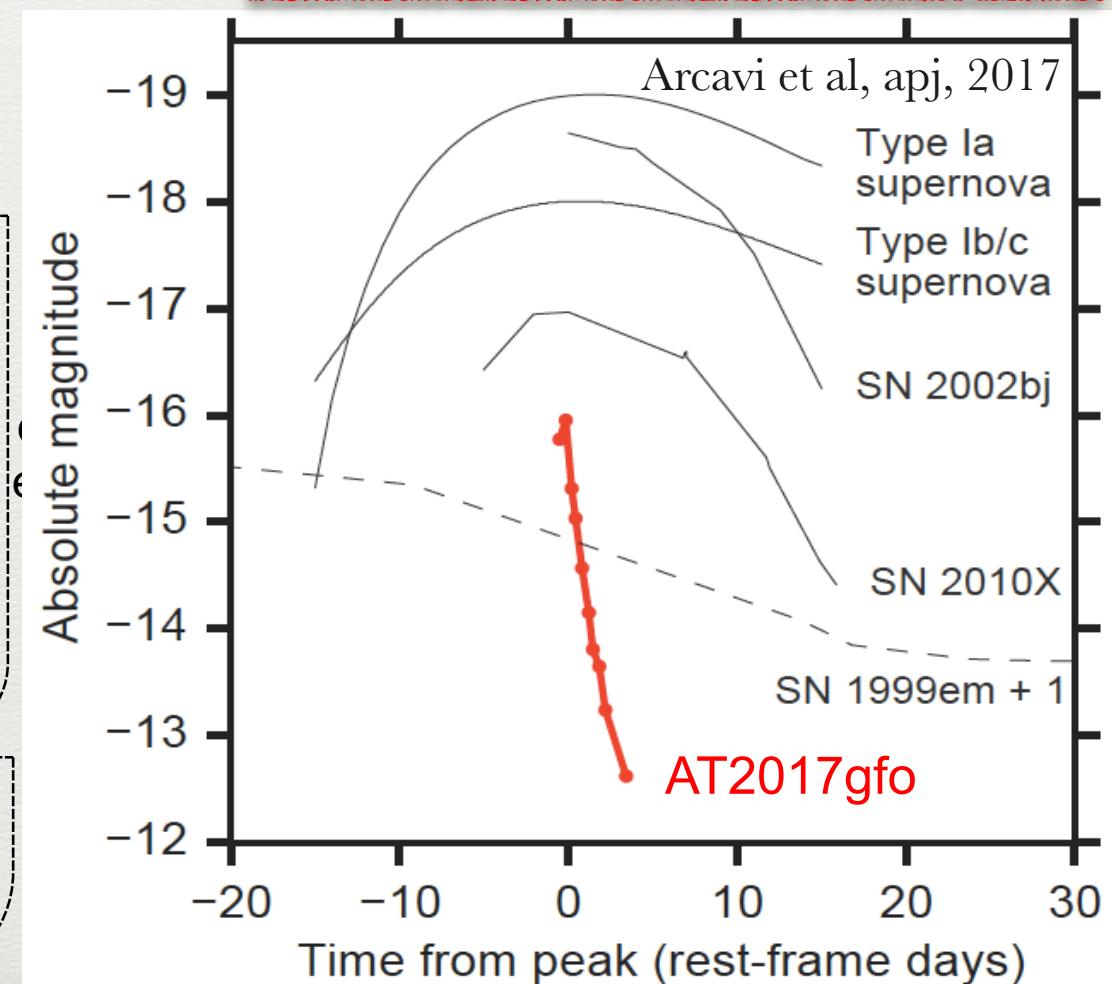
- NS-involved CBC: **KN/GRB**
- BBH: possible but faint
- SN: low chance

KN/GRB: ~days-weeks

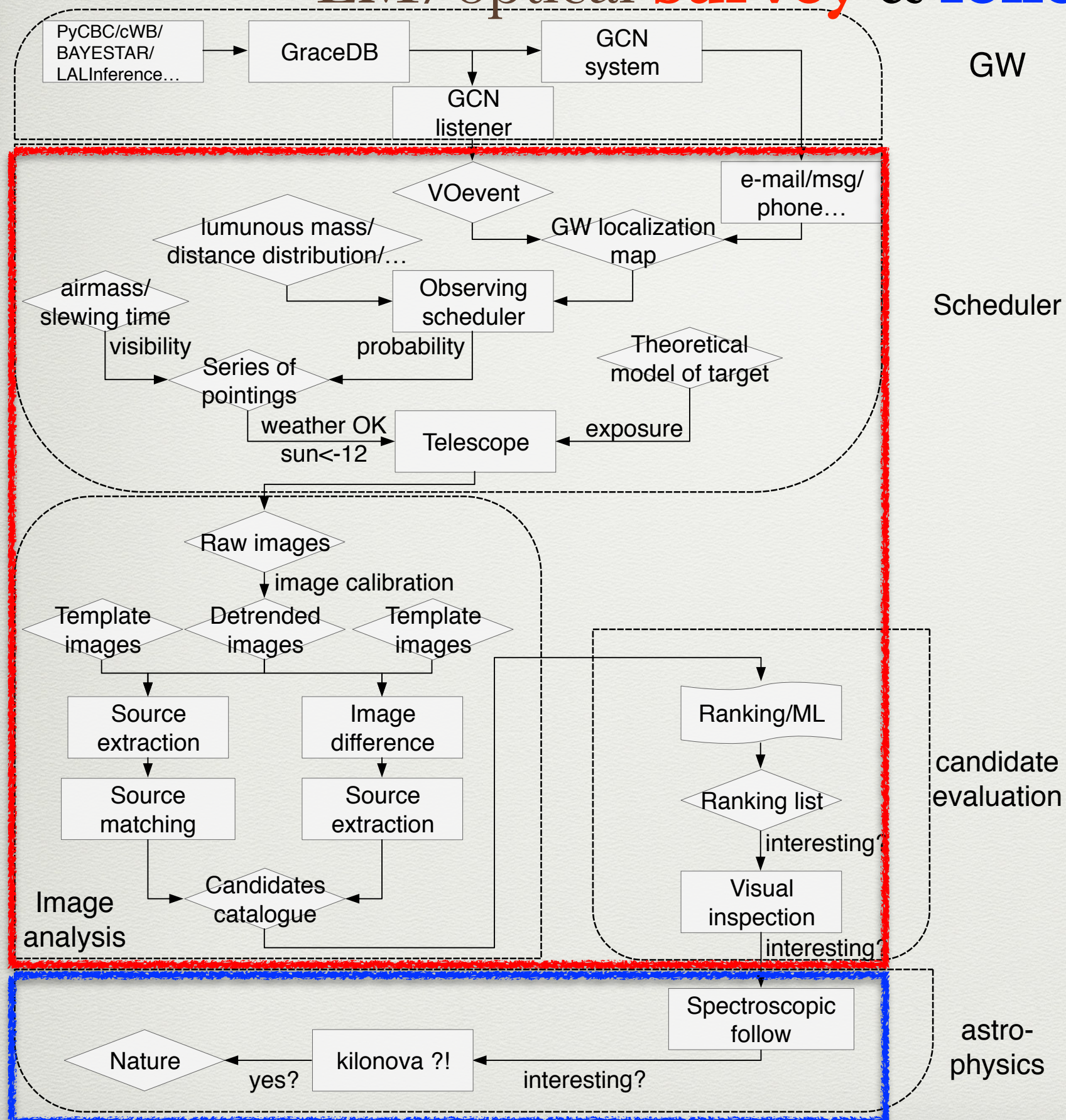
survey:

- **robotic** telescopes
- **automatic** pipelines for image processing
- **machine learning** for transient identification

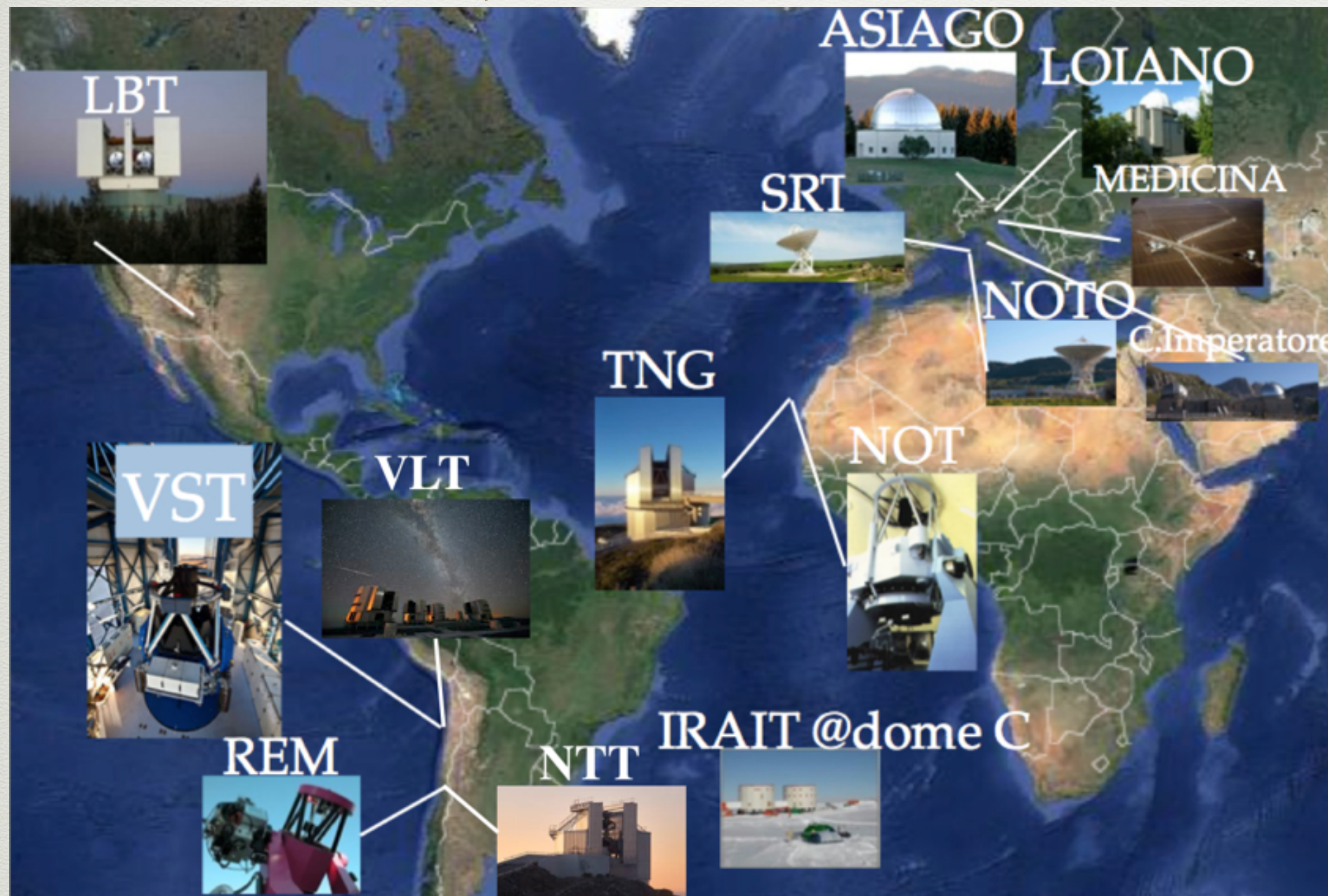
high cadence follow-up is needed !



EM/optical **survey** & **follow-up**



GrawITA - GRAvitational Wave Inaf TeAm



Collaboration:
ePESSTO, SWIFT, Magic,
INTEGRAL, AGILE

**Positive interaction
during O1+O2:**
Pan-Starrs, iPTF, VISTA,
J-GEM

Multi-wavelength Observing Facilities:

<https://www.grawita.inaf.it/>

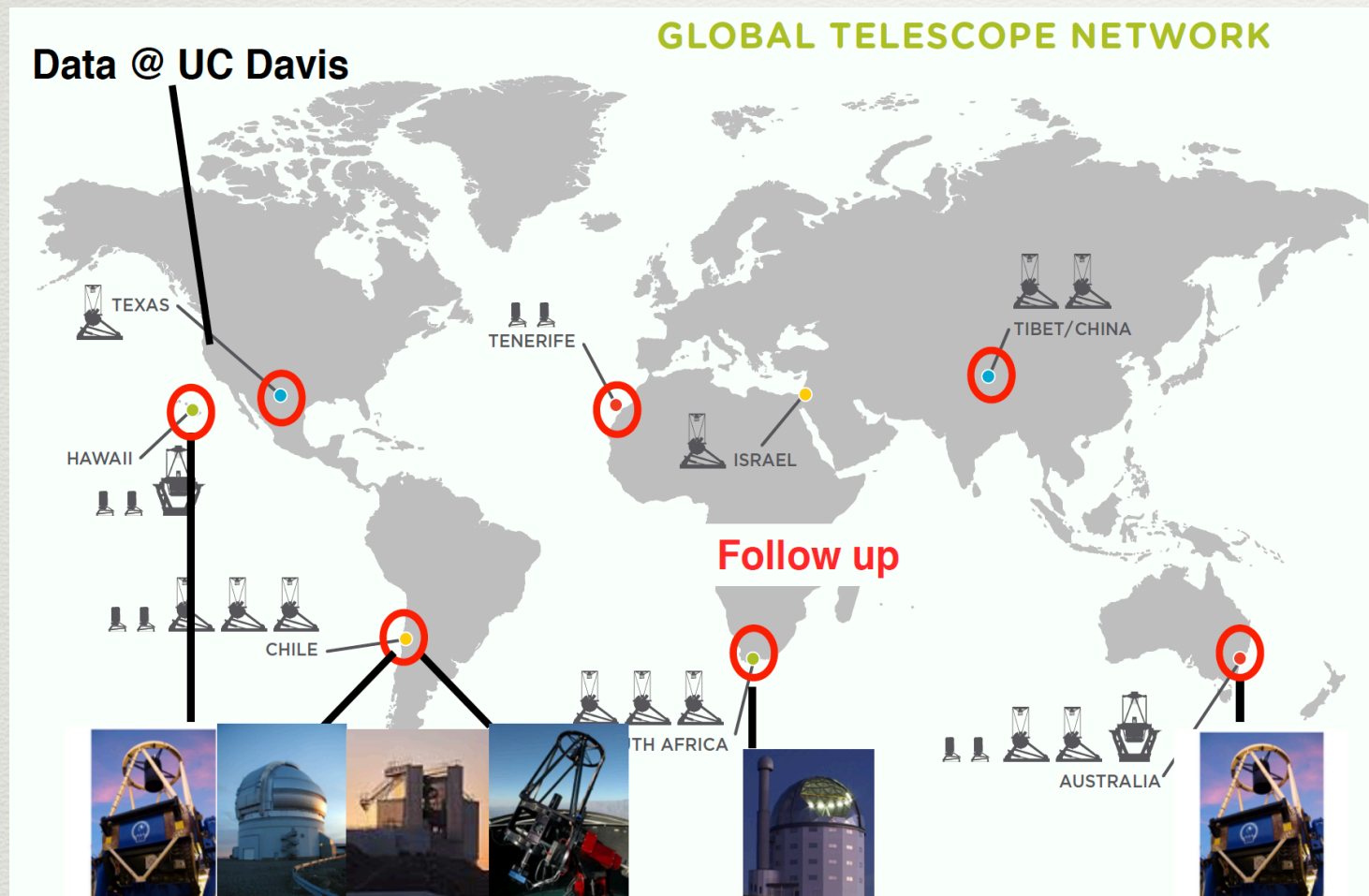
Visible: VST, LBT, TNG, NOT, NTT, VLT + small telescopes [REM, 1.82m (Asiago, IT), Asiago-schmidt, 1.52m (Loiano, IT), 0.9m C. Imperatore, IT)] + HST (coll.)

Near-mid IR: 1.1m AZT-24 (C. Imperatore, IT), IRAIT (Antarctica)

Radio: 64m SRT (Cagliari, IT), 2x 32m (Medicina and Noto, IT)

High energy (coll.): space(coll. Swift, Chandra) + ground (coll. MAGIC, future ASTRI, CTA)

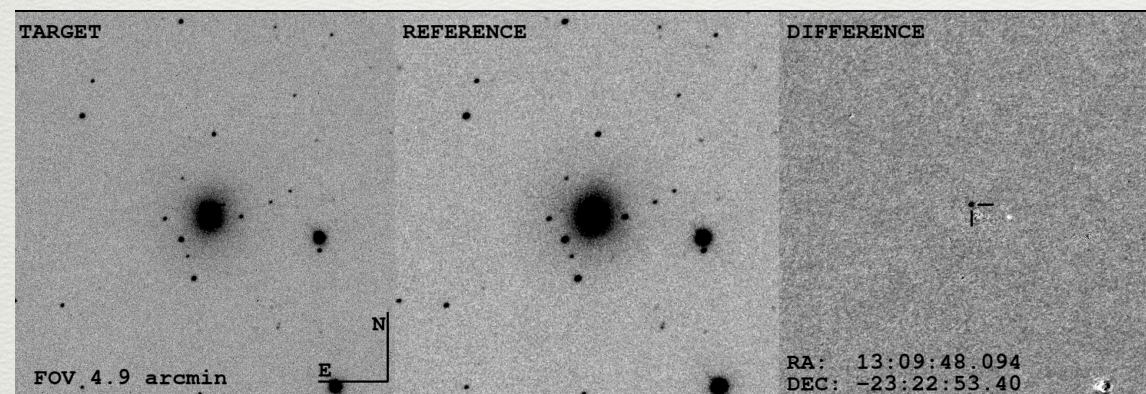
Distance Less Than 40 Mpc survey



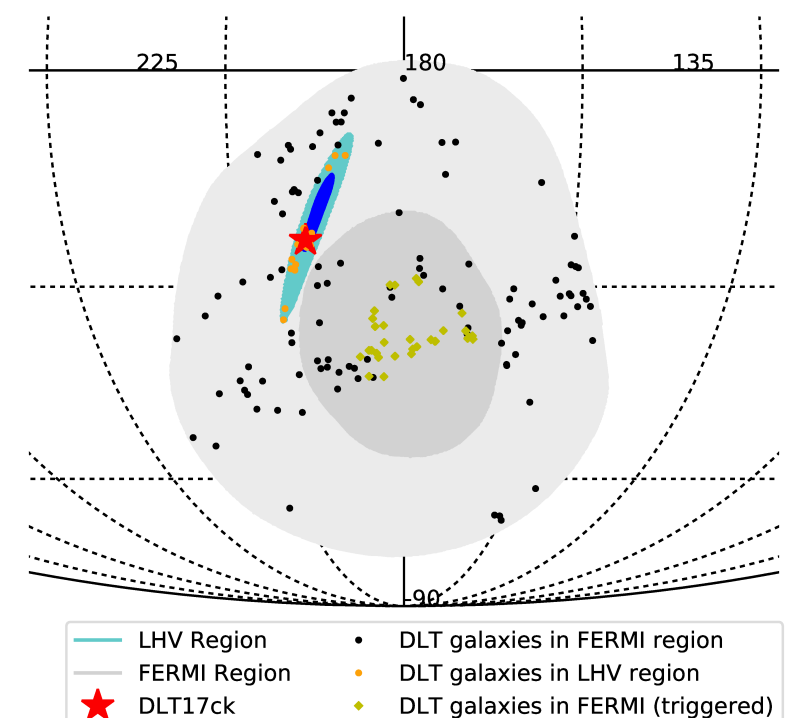
**daily SN search since 2 years ago
+ GW follow-up**

**3*0.4m robotic telescopes with
10*10 arcmin FoV, ~19 mag in r:**

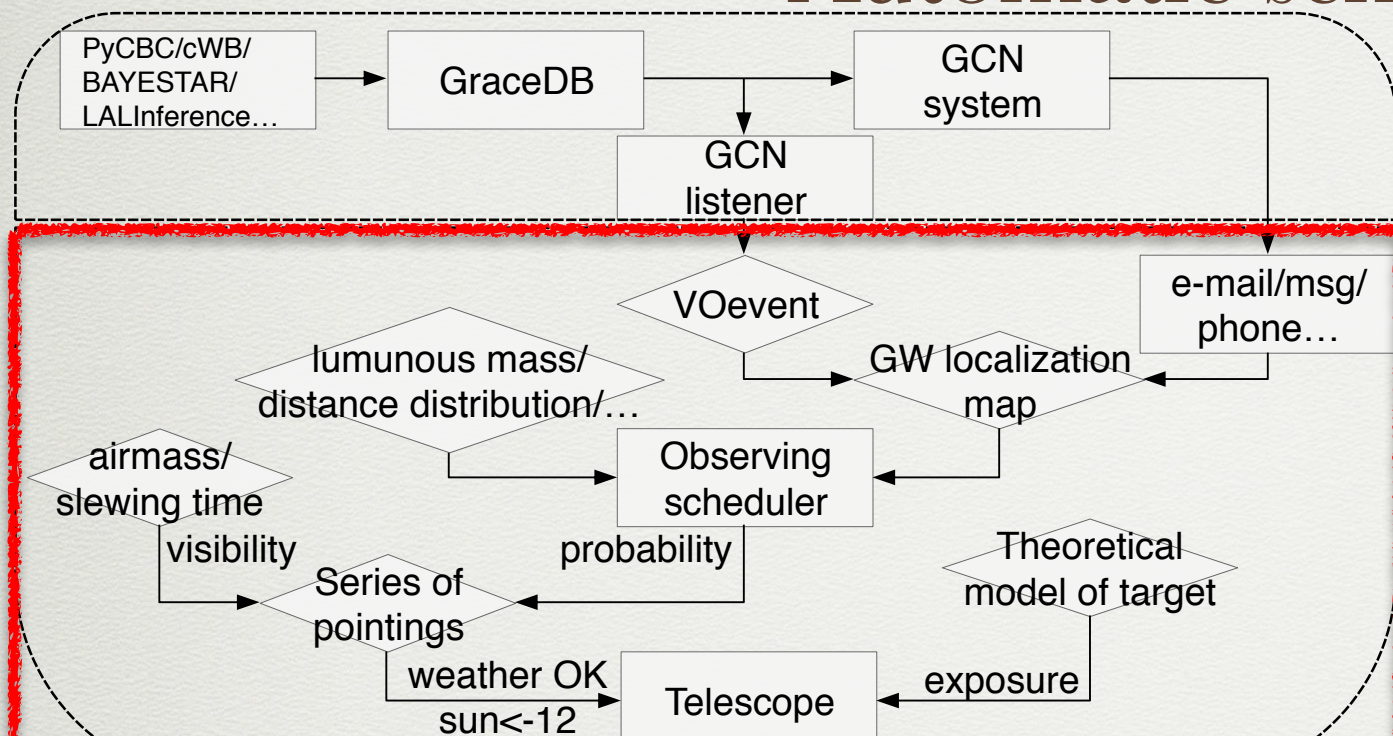
- **O2: PROMPT@CTIO**
- **O3: +PROMPT@Australia
+PROMPT@Canada**



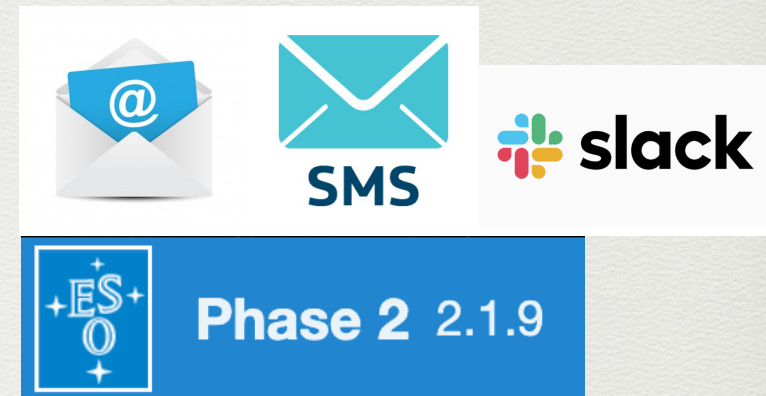
DLT40 independently discovery of KN, AT17gfo/DLT17ck



Automatic scheduler



GW



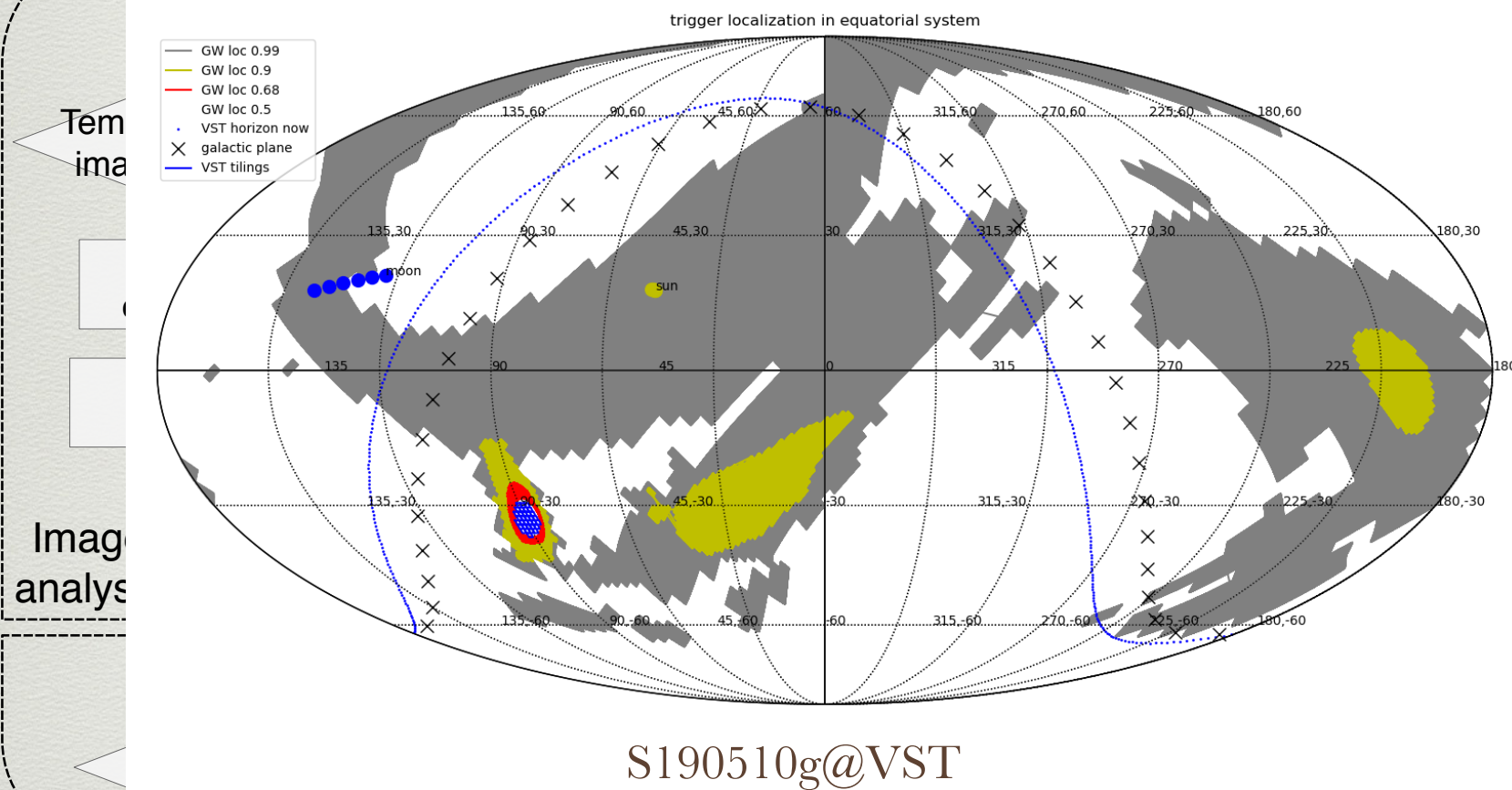
Scheduler

images

ESO/Triest archive

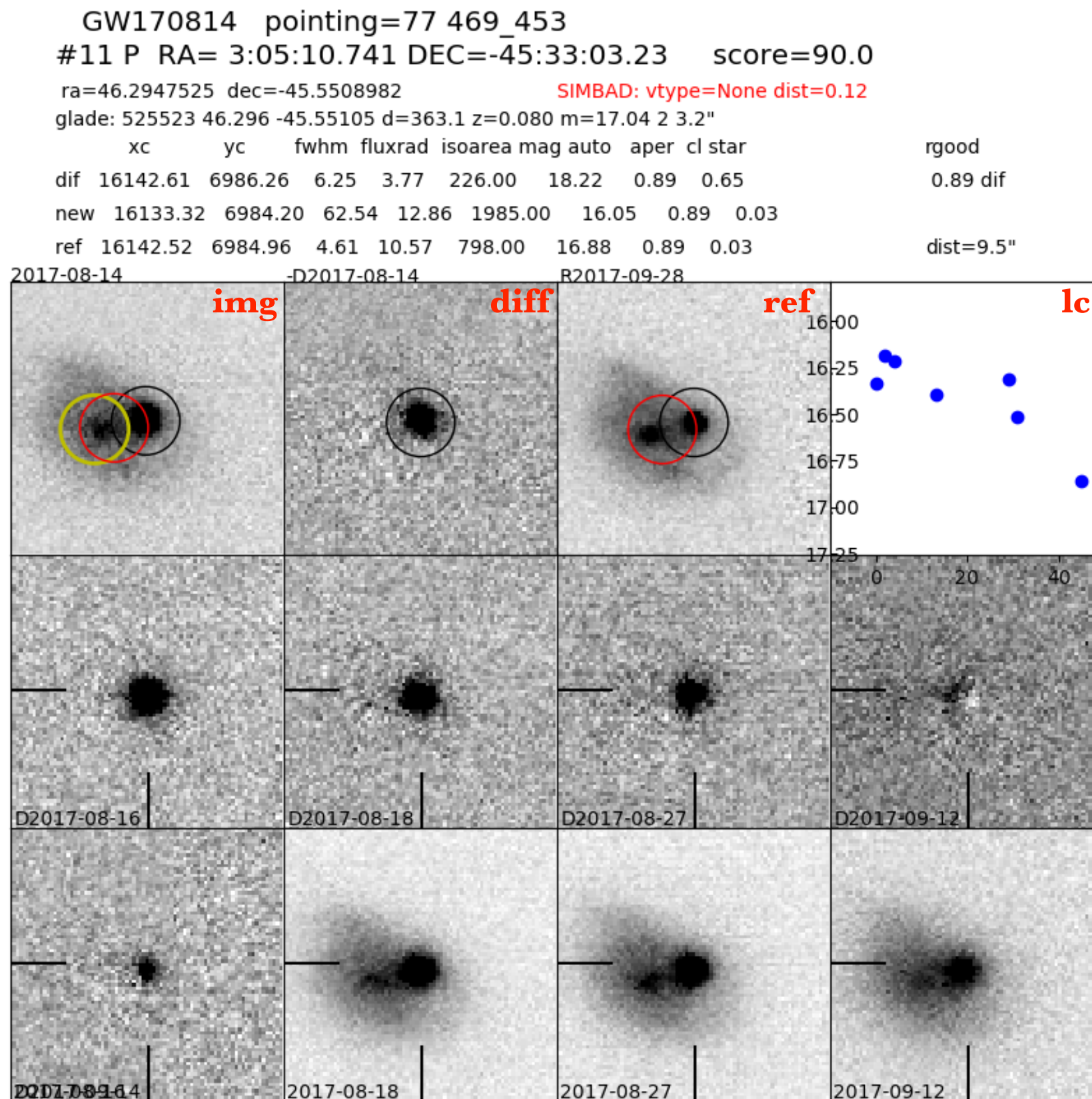
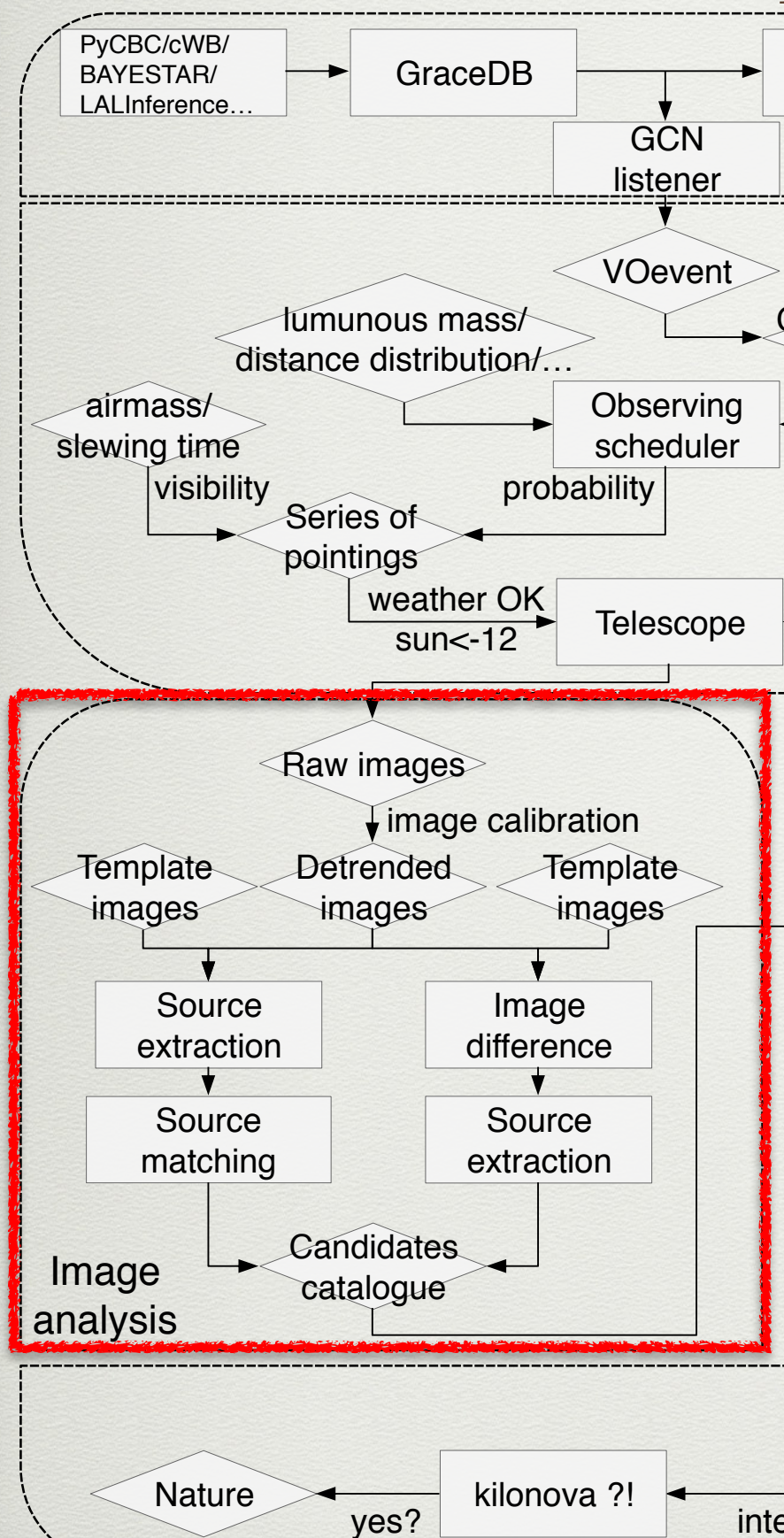
image detrended
e.g. VSTtube (Lino Grado)

GRAWITA cluster (Luciano Nicastro)

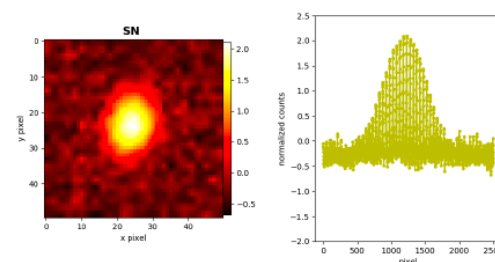
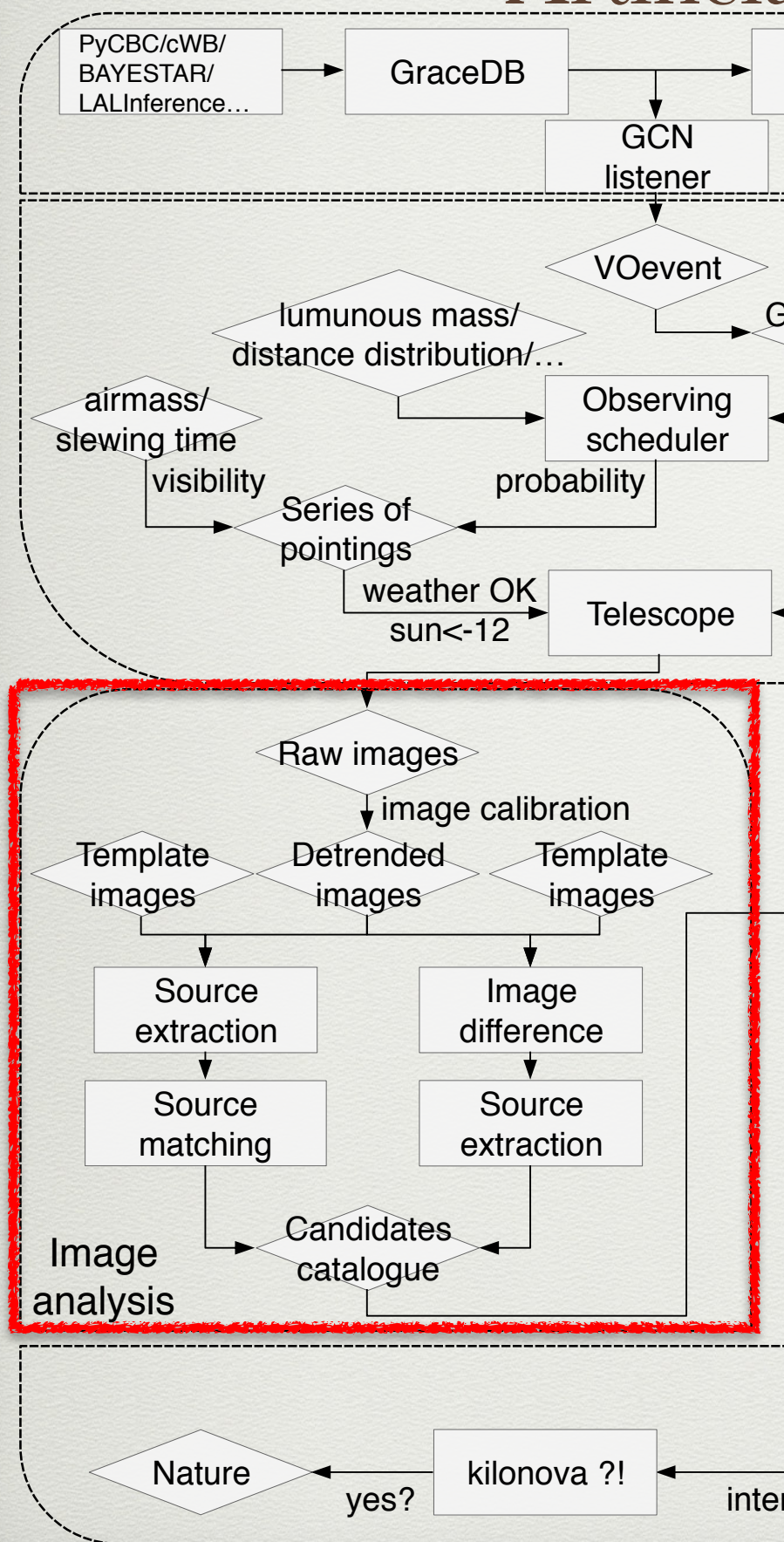


S190510g@VST

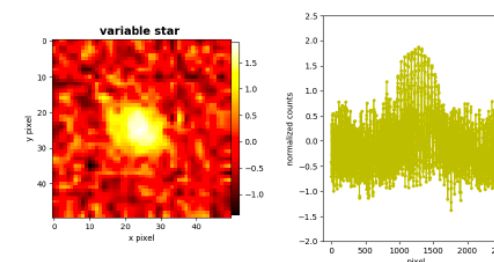
Image difference



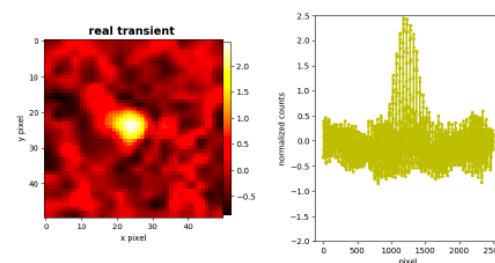
Artificial Intelligence is needed



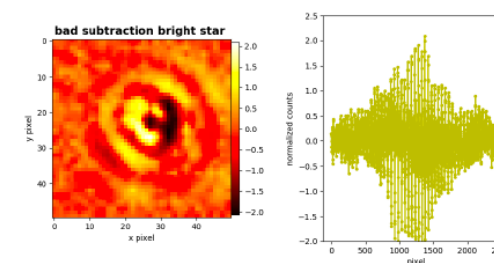
(a) supernova



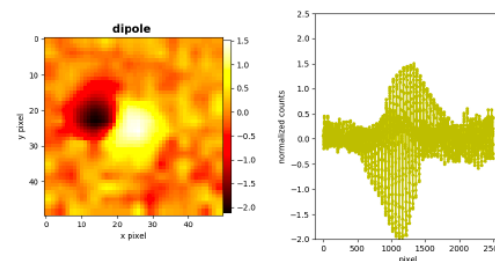
(b) variable star



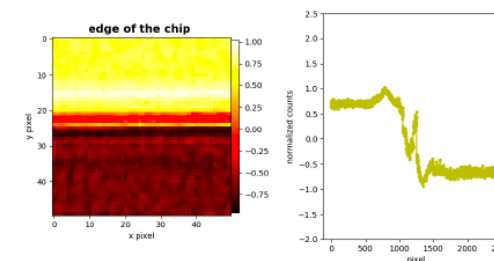
(c) real transient



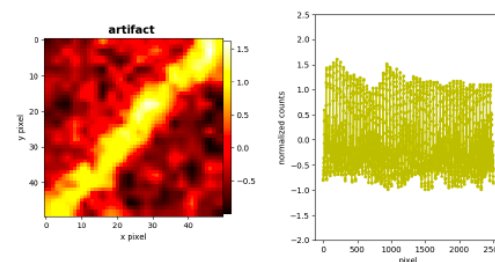
(d) bright star



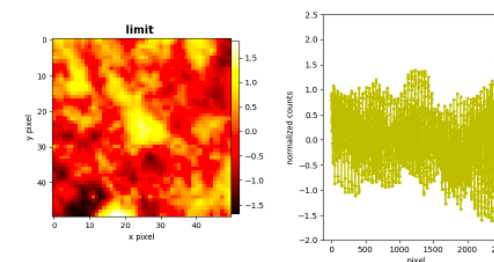
(e) dipole



(f) edge



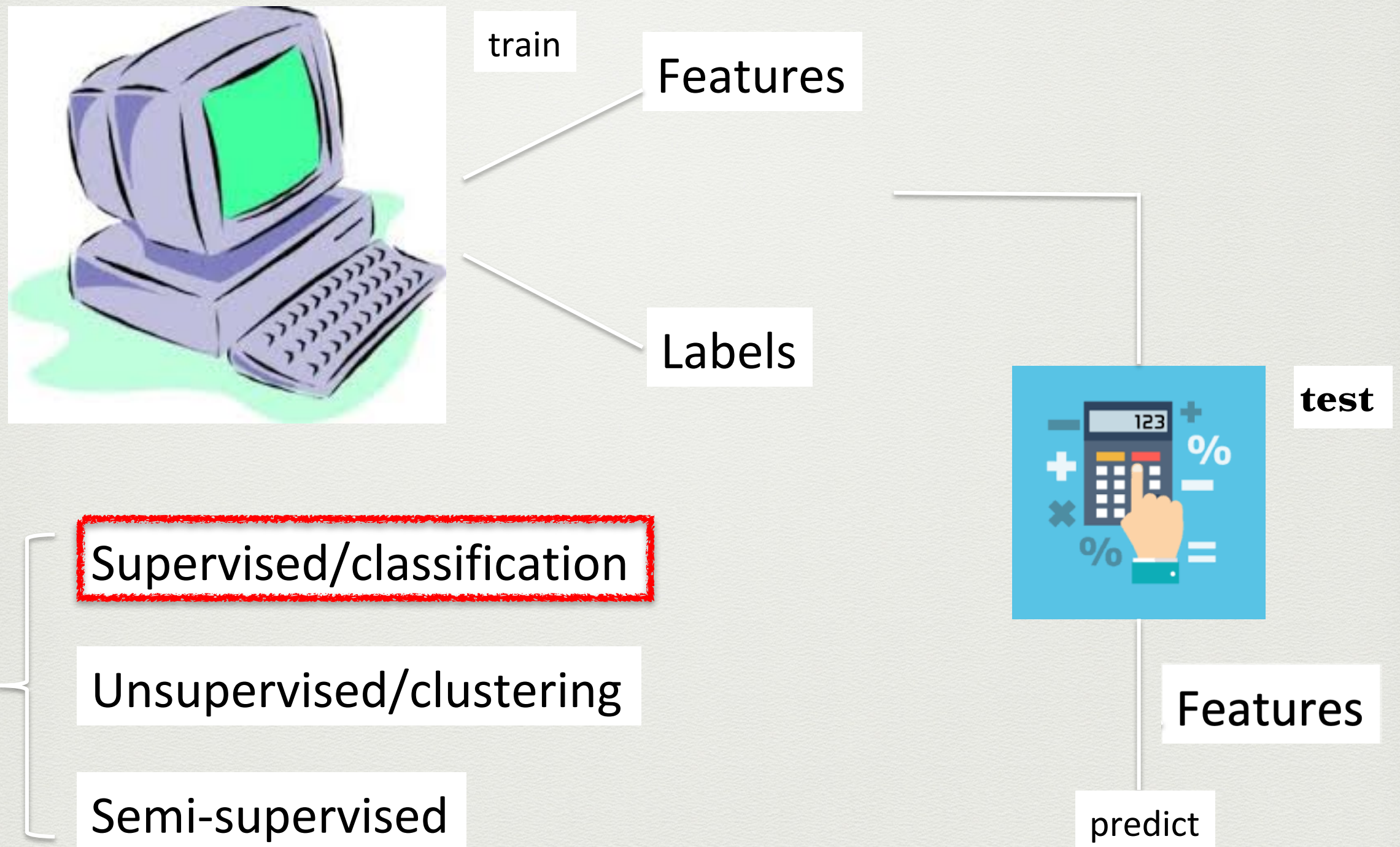
(g) artifact



(h) limit

setting $S/N=3$, there're on average 1000-10000 detections on difference images, among which there're majority of bogus (1/100)

Auto candidate evaluation: Machine Learning (ML)



Auto candidate evaluation: Machine Learning (ML)

historical/simulated data is needed !



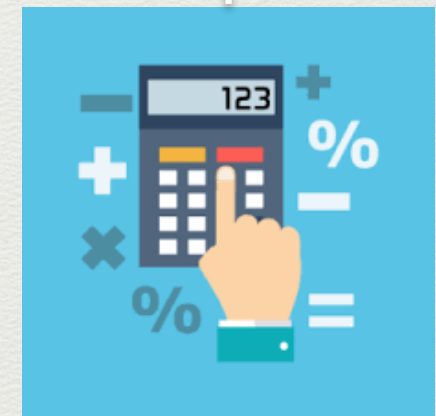
train

Features

Labels

online ML: with infos from only one point

- stamp matrix
- catalog infos
- PCA
-

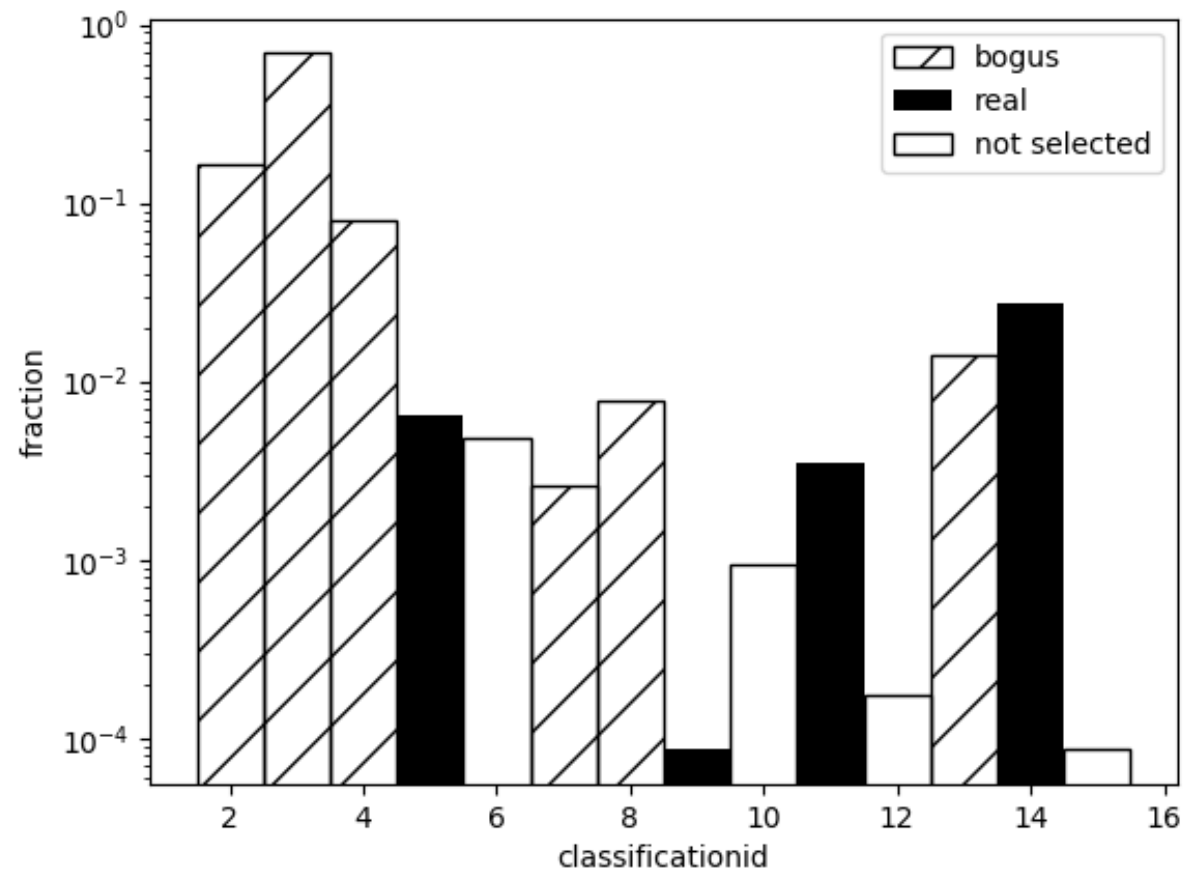


test

Features

predict

ML with DLT40



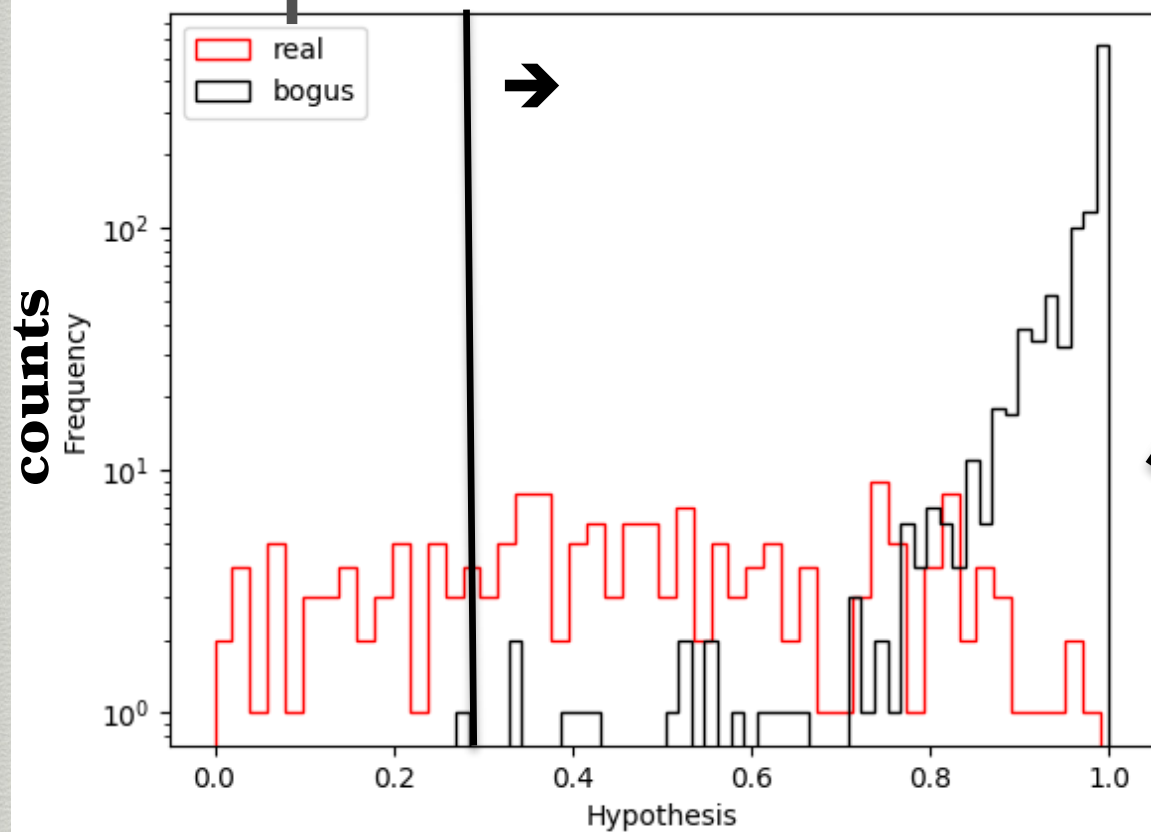
d	classification	ML_id
1	eyeball	NULL
2	bad subtraction	0
3	bad subtraction bright star	0
4	dipole	0
5	real transient	1
6	moving object	NULL
7	edge of the chip	0
8	artifact	0
9	AGN	NULL
10	artificial star	1
11	SN	1
12	CV	NULL
13	rings	0
14	variable star	NULL
15	limit	0
16	kilonova	1

~60,000 candidates were visual inspected during 2 years.

ML evaluation: figure of merit (FOM)

eyeballing
results

A test on DLT40 object



estimation by ML

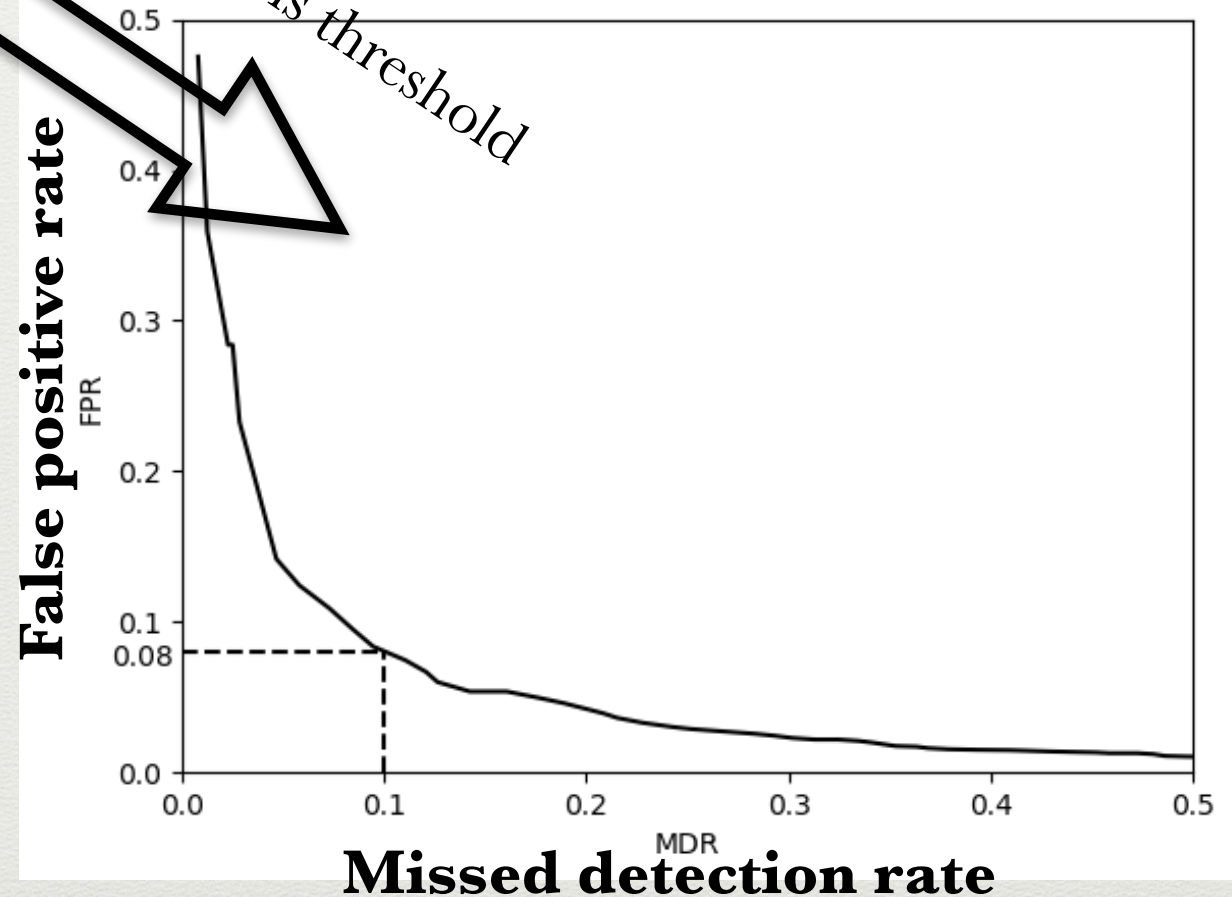
hypothesis histogram

split known sample into training and testing set,
so that testing set is known

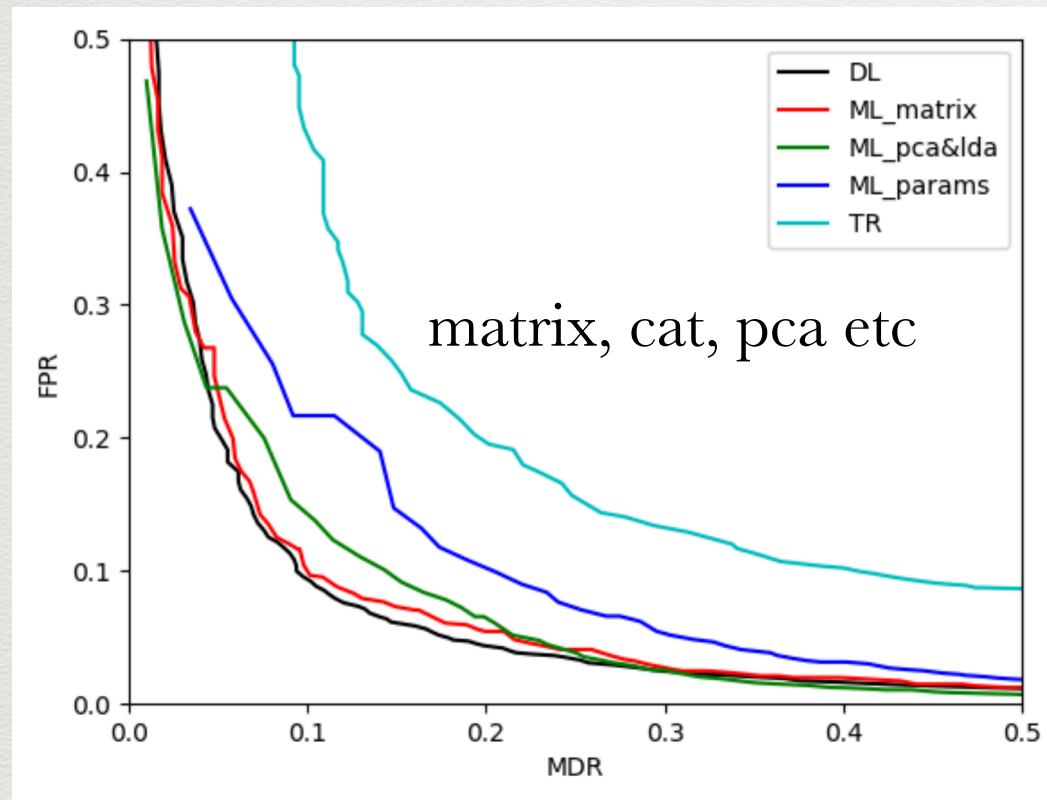
ROC curve

- the lower, the better.

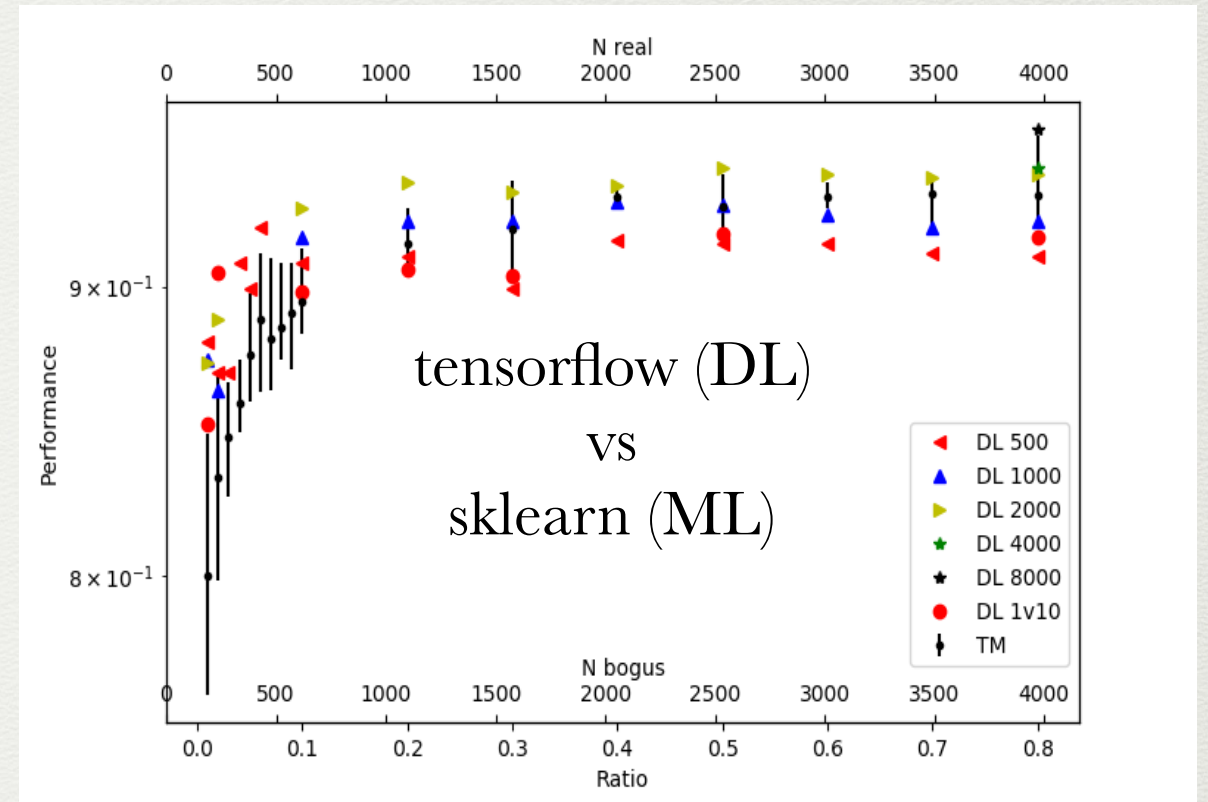
running hypothesis threshold



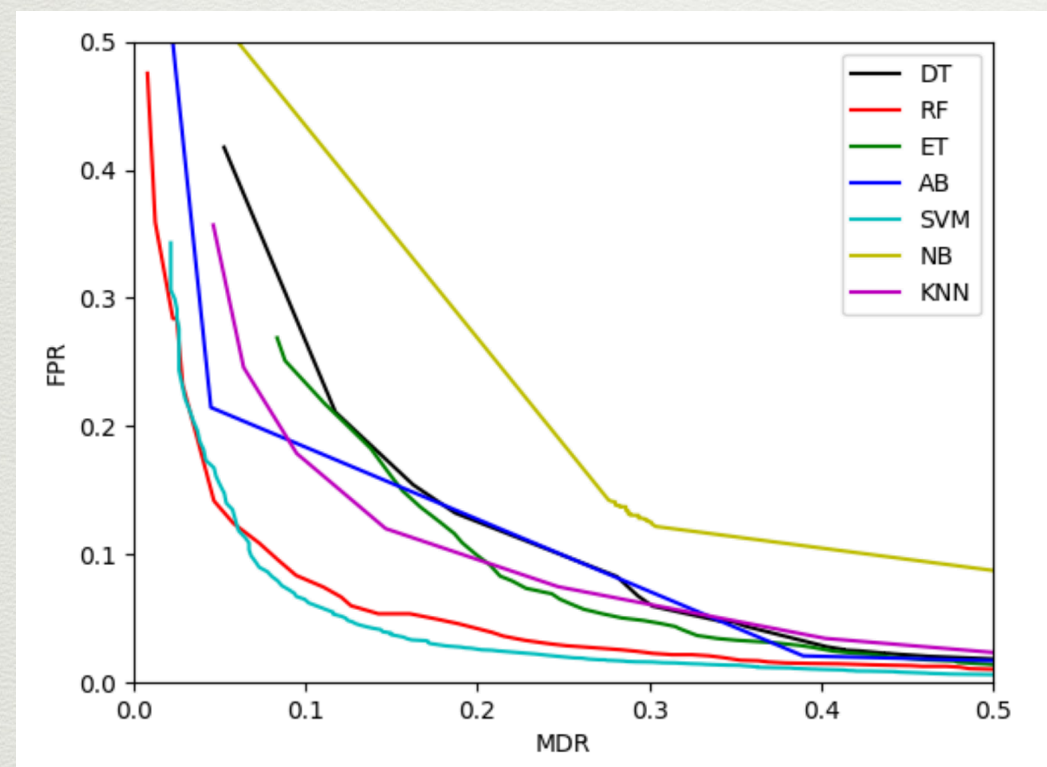
ML optimization



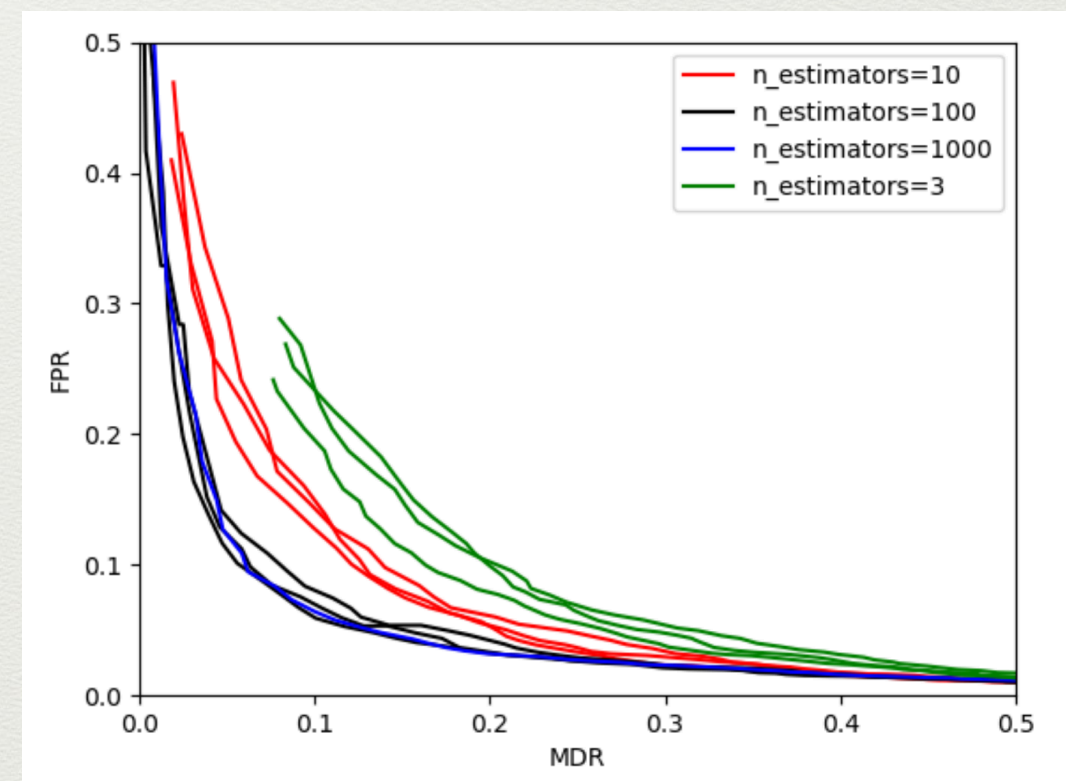
20*20 pixel stamps.



scikit-learn

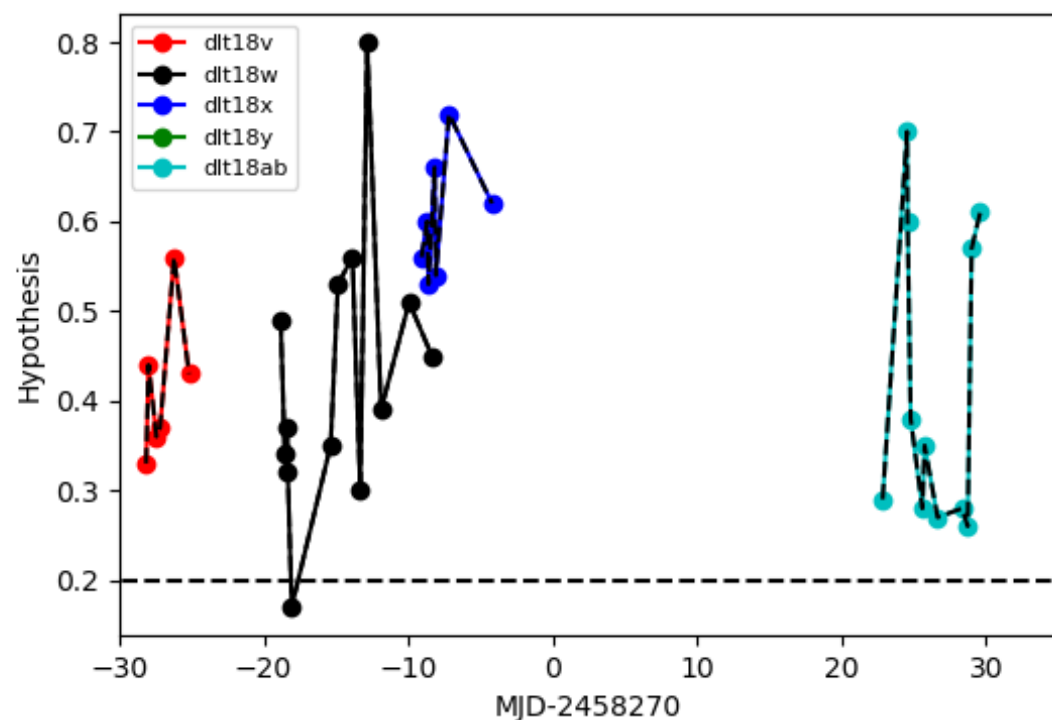
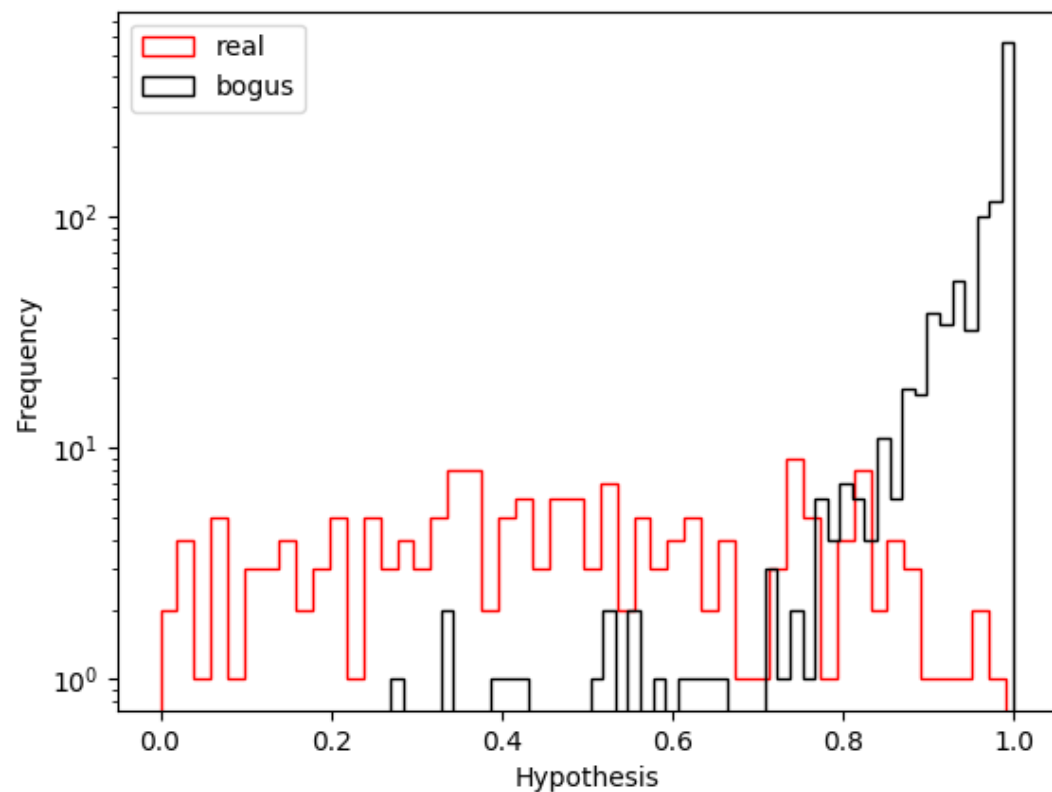


random forest classifier



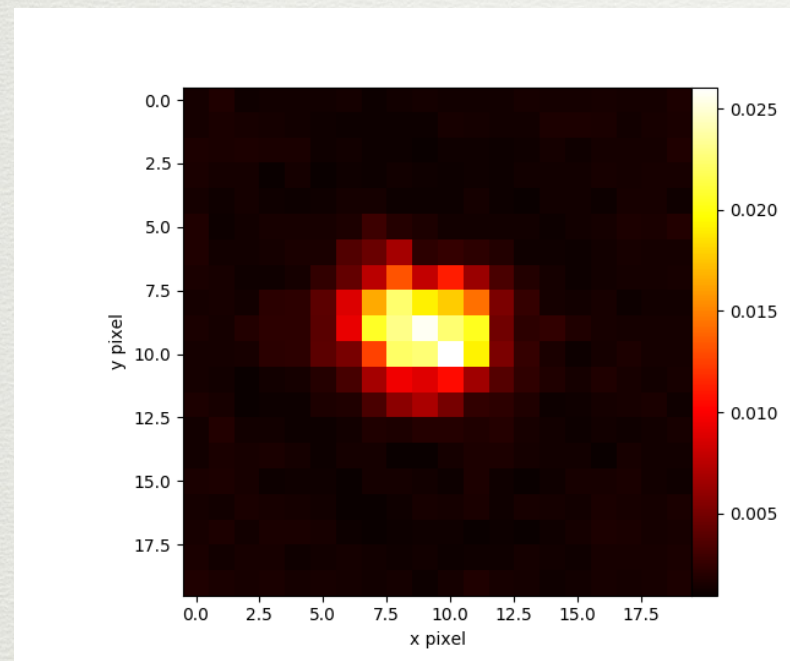
RF with 100 estimators

ML implementation on ongoing DLT40 SN search



- a random forest classifier is employed by DLT40 daily SN search from the end of April, 2018
- ~ 20 Atels till now with ML detection
- transient rate is consistent with no ML, however, reducing candidate number from x,000 to x,0

‘cross-telescope’ ML implementation



Feature importance

DLT40 memory on VST & Asiago schmidt:

- stamp size \sim FWHM
- log normalization: SNR
- testing with S190510g@VST

