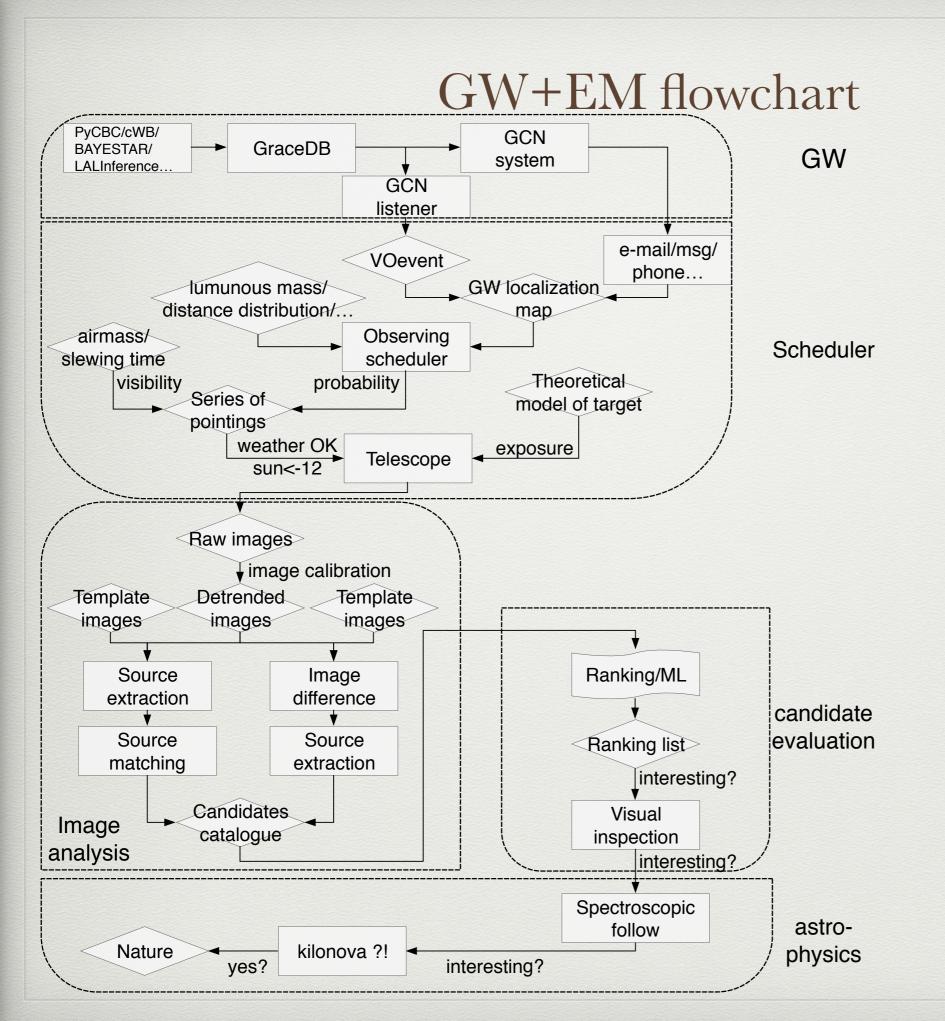


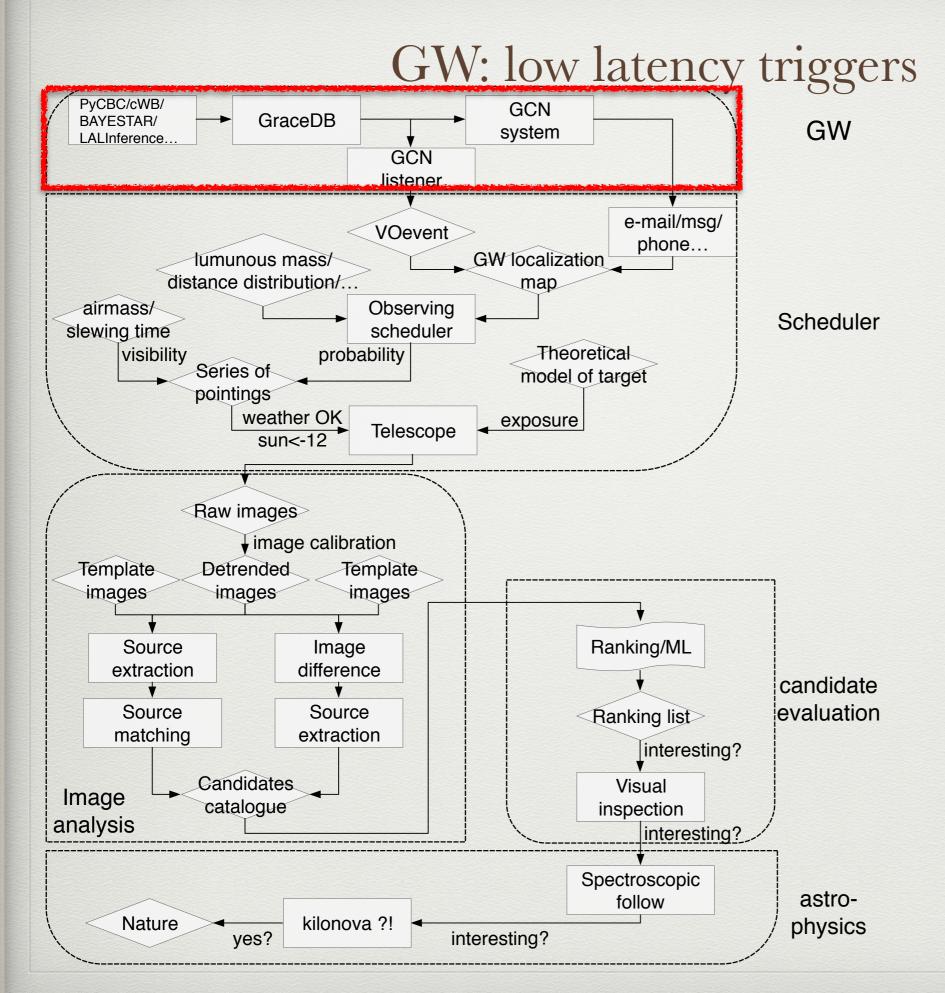


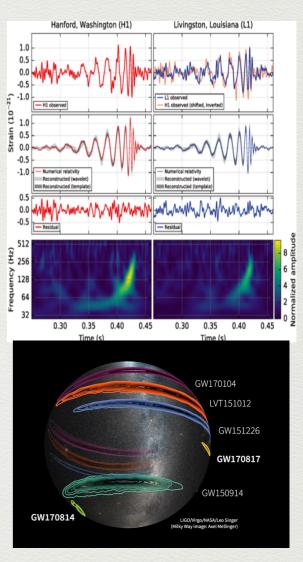
MACHINE LEARNING IMPLEMENTATION IN THE MULTIMESSENGER SEARCH OF GRAVITATIONAL WAVE SOURCES

Sheng Yang (OAPD, INAF)

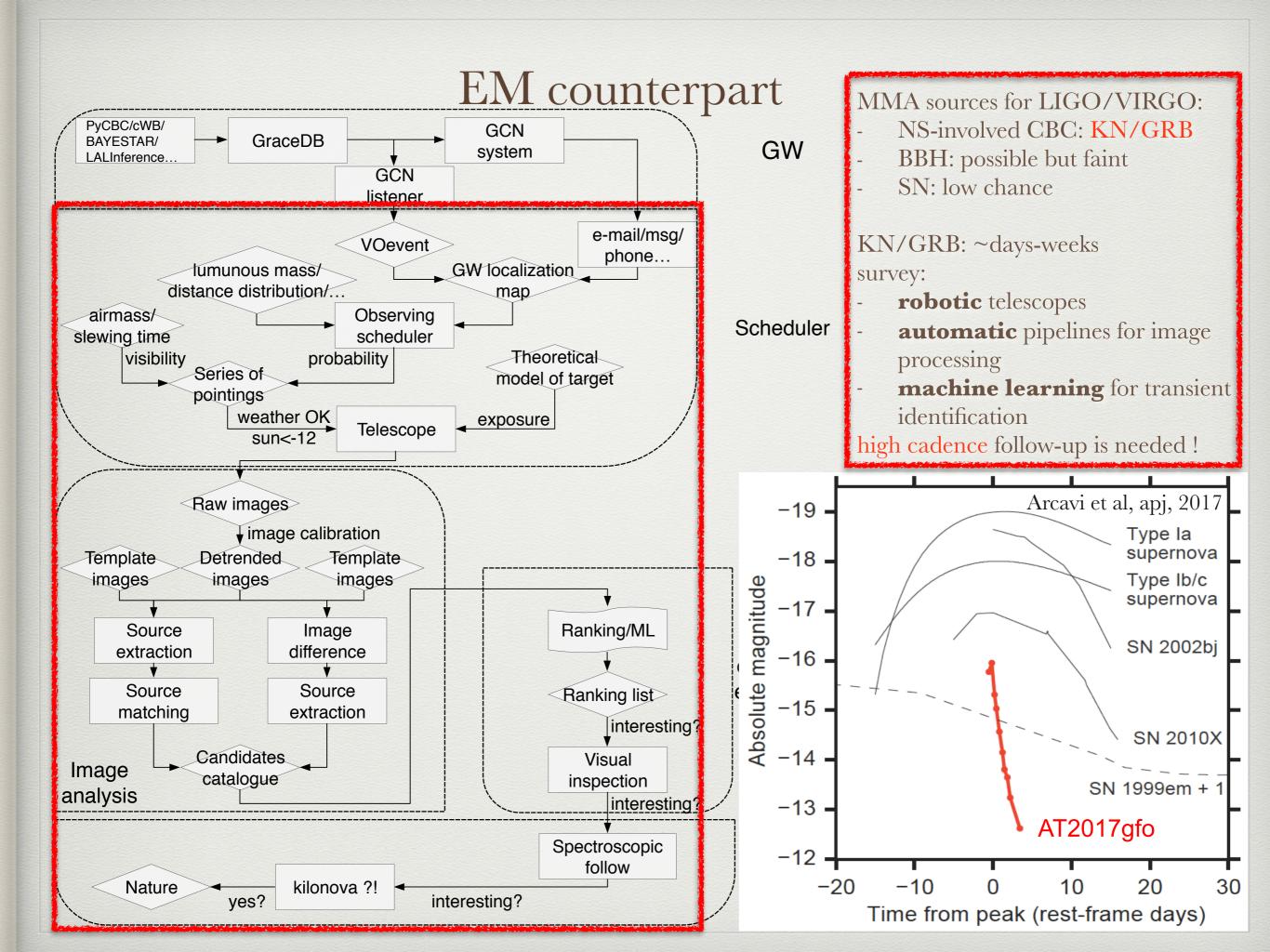
2019/6/19@Roma INAF Science Archives & the Big Data Challenge





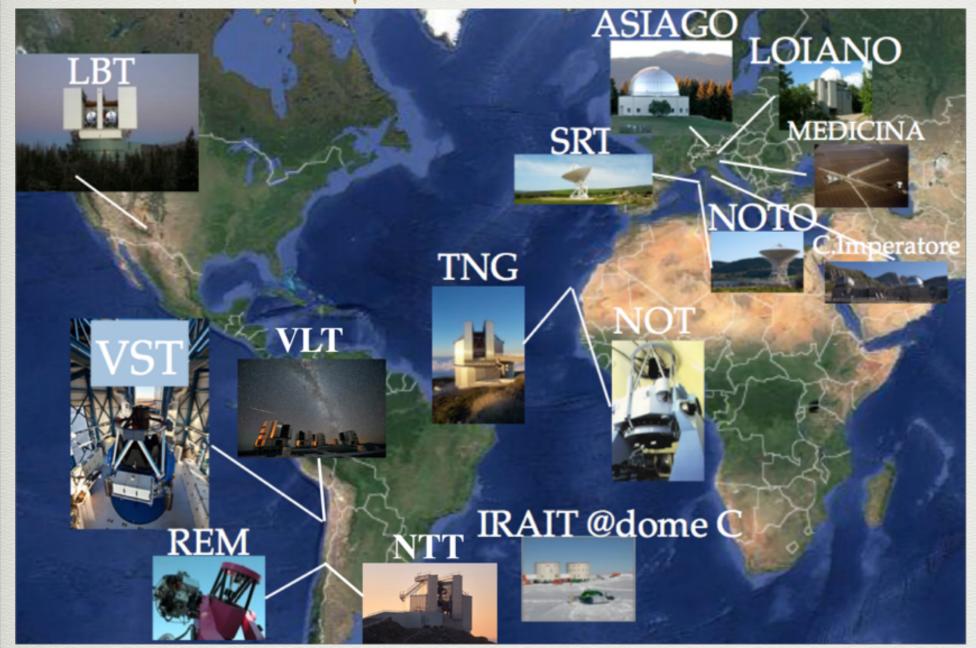


analytic GW analysis: ~hours



EM/optical survey & follow-up PyCBC/cWB/ **GCN** GraceDB BAYESTAR/ GW system LALInference. GCN listener e-mail/msg/ VOevent phone... GW localization lumunous mass/ distance distribution/... map Observing airmass/ Scheduler scheduler slewing time Theoretical probability visibility Series of model of target pointings weather OK exposure Telescope sun<-12 Raw images √ image calibration Template Detrended Template images images images Ranking/ML Source Image extraction difference candidate evaluation Source Source Ranking list extraction matching interesting' Candidates Visual Image catalogue inspection analysis interesting Spectroscopic astrofollow Nature kilonova?! physics ves? interesting?

© Ta Word 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/

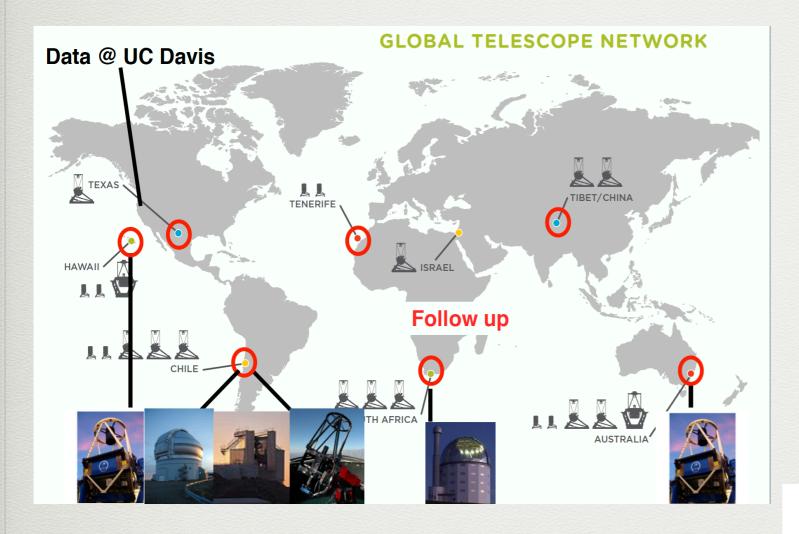
Visible: VST, LBT, TNG, NOT, NTT, VLT + small telescopes [REM, 1.82m (Asiago, IT), Asiago-schmidt, 1.52m (Loiano, IT), 0.9m C. Imperatore, IT)] + HST (coll.)

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



TARGET REFERENCE DIFFERENCE

N

RA: 13:09:48.094

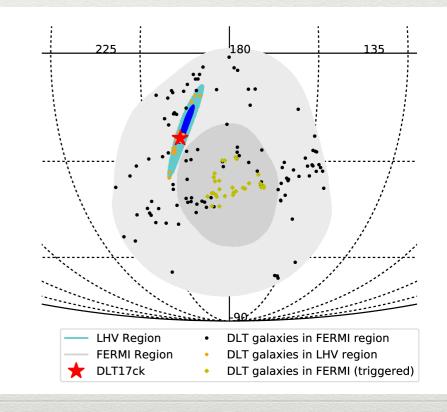
DEC: -23:22:53.40

DLT40 independently discovery of KN, AT17gfo/DLT17ck

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

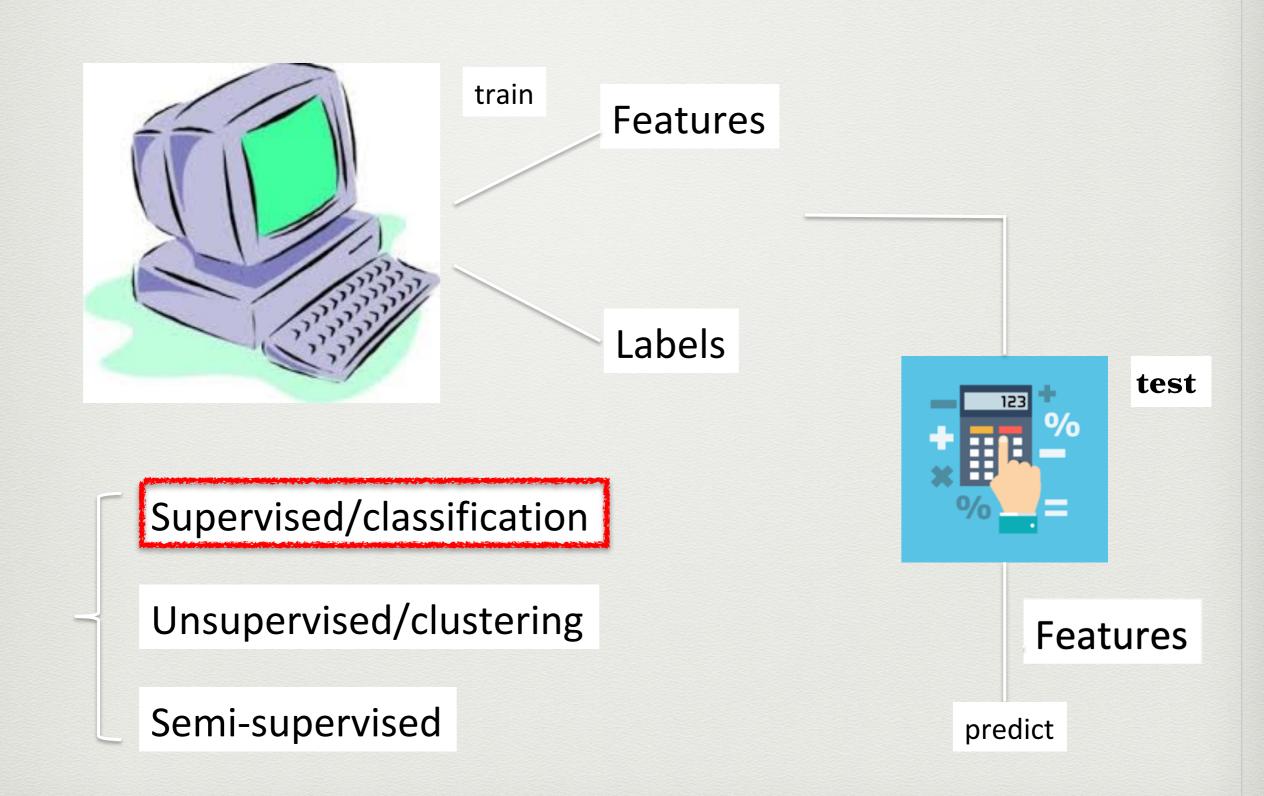


Automatic scheduler PyCBC/cWB/ **GCN** GraceDB BAYESTAR/ GW system LALInference.. GCN # slack listener e-mail/msg/ VOevent phone... GW localization lumunous mass/ Phase 2 2.1.9 distance distribution/... map airmass/ Observing Scheduler scheduler slewing time Theoretical probability visibility Series of model of target images pointings weather OK exposure Telescope **ESO/Triest archive** trigger localization in equatorial system GW loc 0.99 - GW loc 0.9 GW loc 0.68 Tem X galactic plane ima VST tilings image detrended e.g. VSTtube (Lino Grado) Imag analys **GRAWITA** cluster (Luciano Nicastro) S190510g@VST

Image difference PyCBC/cWB/ GW170814 pointing=77 469_453 BAYESTAR/ GraceDB LALInference. #11 P RA= 3:05:10.741 DEC=-45:33:03.23 score=90.0 **GCN** ra=46.2947525 dec=-45.5508982 SIMBAD: vtype=None dist=0.12 listener glade: 525523 46.296 -45.55105 d=363.1 z=0.080 m=17.04 2 3.2" fwhm fluxrad isoarea mag auto aper cl star rgood **VOevent** 0.89 0.65 dif 16142.61 6986.26 6.25 3.77 226.00 18.22 0.89 dif lumunous mass/ new 16133.32 6984.20 62.54 12.86 1985.00 16.05 0.89 0.03 distance distribution/... ref 16142.52 6984.96 4.61 10.57 798.00 16.88 0.89 0.03 dist=9.5" airmass/ Observing 2017-08-14 -D2017-08-14 R2017-09-28 slewing time scheduler img lc 16 00 probability visibility Series of pointings weather OK 16 50 Telescope sun<-12 16-75 17/00 Raw images image calibration Template Detrended Template images images images Source Image extraction difference Source Source D2017-08-16 matching extraction Candidates Image catalogue analysis Nature kilonova?! 2017-08-27 2017-09-12 yes? inte. Julia

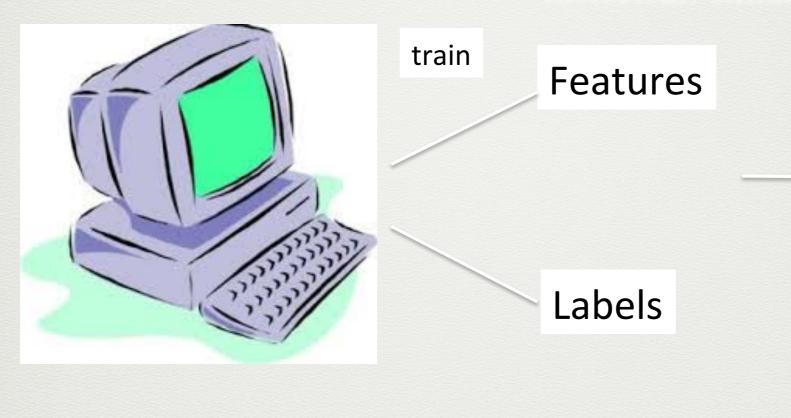
Artificial Intelligence is needed PyCBC/cWB/ GraceDB BAYESTAR/ LALInference. **GCN** listener **VOevent** lumunous mass/ (a) supernova (b) variable star distance distribution/... airmass/ Observing scheduler slewing time probability visibility Series of pointings weather OK Telescope sun<-12 (c) real transient (d) bright star Raw images **√** image calibration Template Detrended Template images images images Source Image (e) dipole (f) edge extraction difference Source Source matching extraction Candidates Image catalogue analysis (g) artifact (h) limit setting S/N=3, there're on average Spectroscopic 1000-10000 detections on difference astrofollow images, among which there're **Nature** kilonova?! physics yes? interesting? majority of bogus (1/100)

Auto candidate evaluation: Machine Learning (ML)



Auto candidate evaluation: Machine Learning (ML)

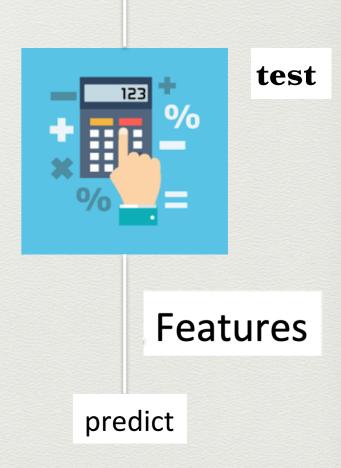
historical/simulated data is needed!



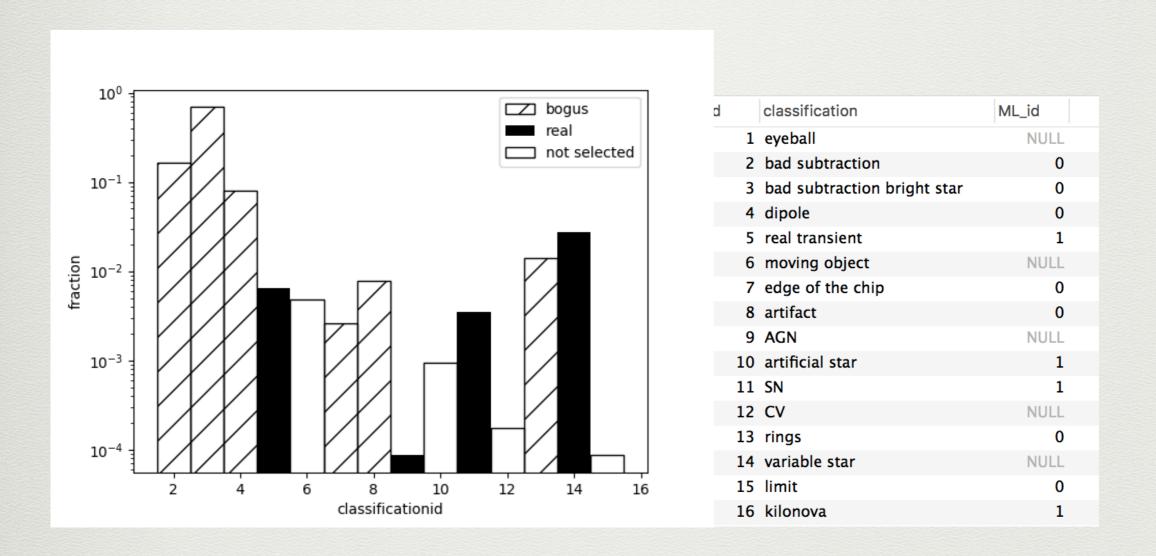
online ML: with infos from only one point

- stamp matrix
- catalog infos
- PCA

. . . .

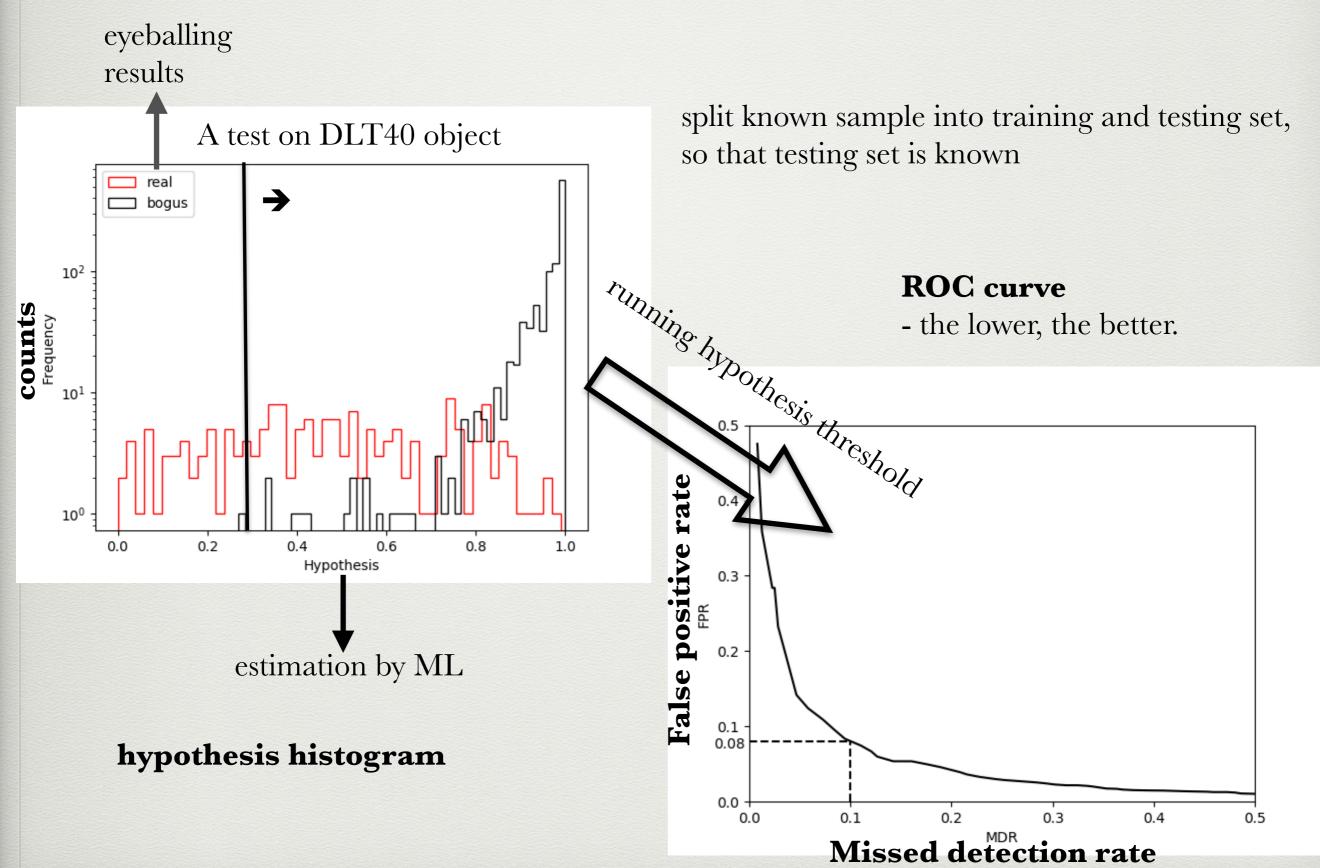


ML with DLT40

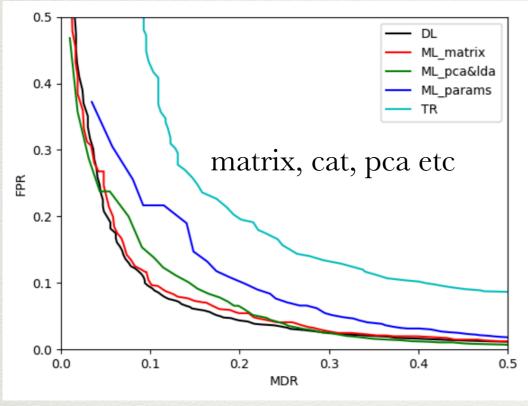


~60,000 candidates were visual inspected during 2 years.

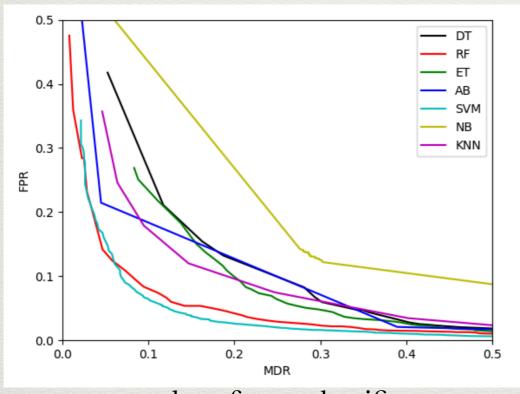
ML evaluation: figure of merit (FOM)



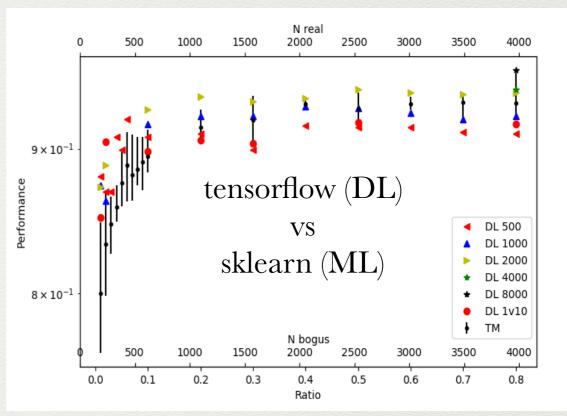
ML optimization



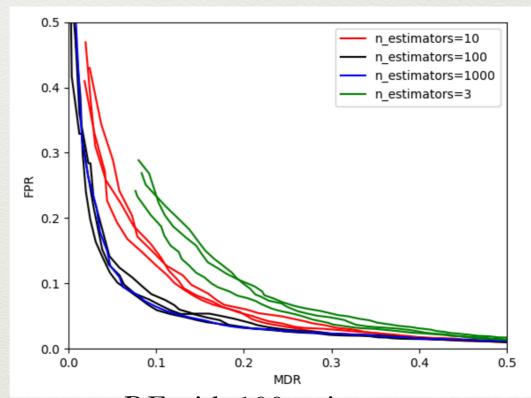
20*20 pixel stamps.



random forest classifier

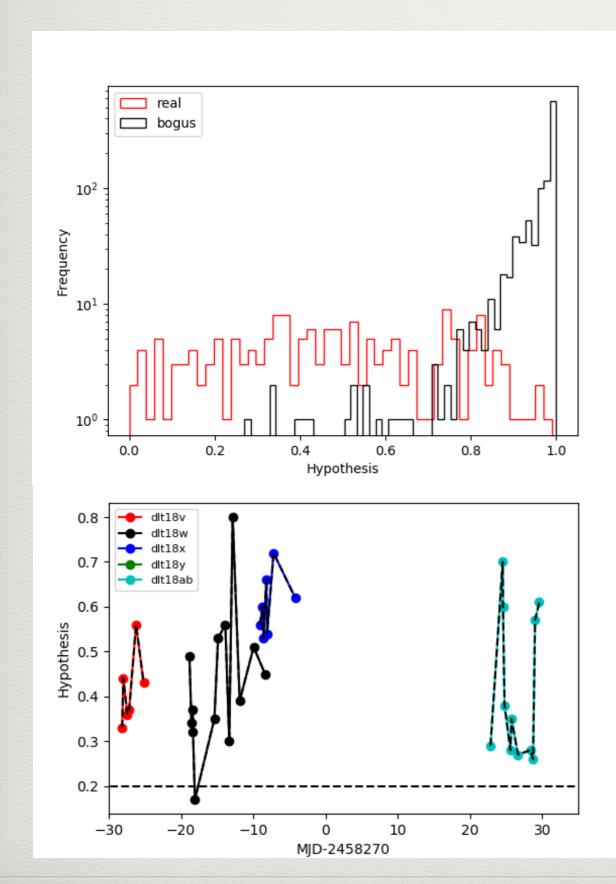


scikit-learn



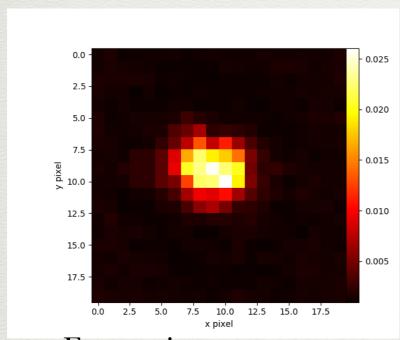
RF with 100 estimators

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 ~ FWHM
- log normalization: SNR
- testing with S190510g@VST

