Optimising a spectroscopic training sample with 4MOST

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4MOST-TiDES team

TiDES: Time Domain Extragalactic Survey

- Everywhere 4MOST points, there will be known transients
- TiDES will use ~2% of 4MOST low-res fibres in extragalactic fields
- Three goals
  - Redshifts of SN host galaxies, after the SN has faded – up to 50,000
  - Spectra of live transients: classification, rare transients - up to 30,000
  - AGN reverberation mapping
- Allocation of 250,000 fibre hours - survey design underway now
- See Swann et al 2019

TiDES founding institiutes

University of Portsmouth | University of Southampton | Queen's University Belfast | Lancaster University

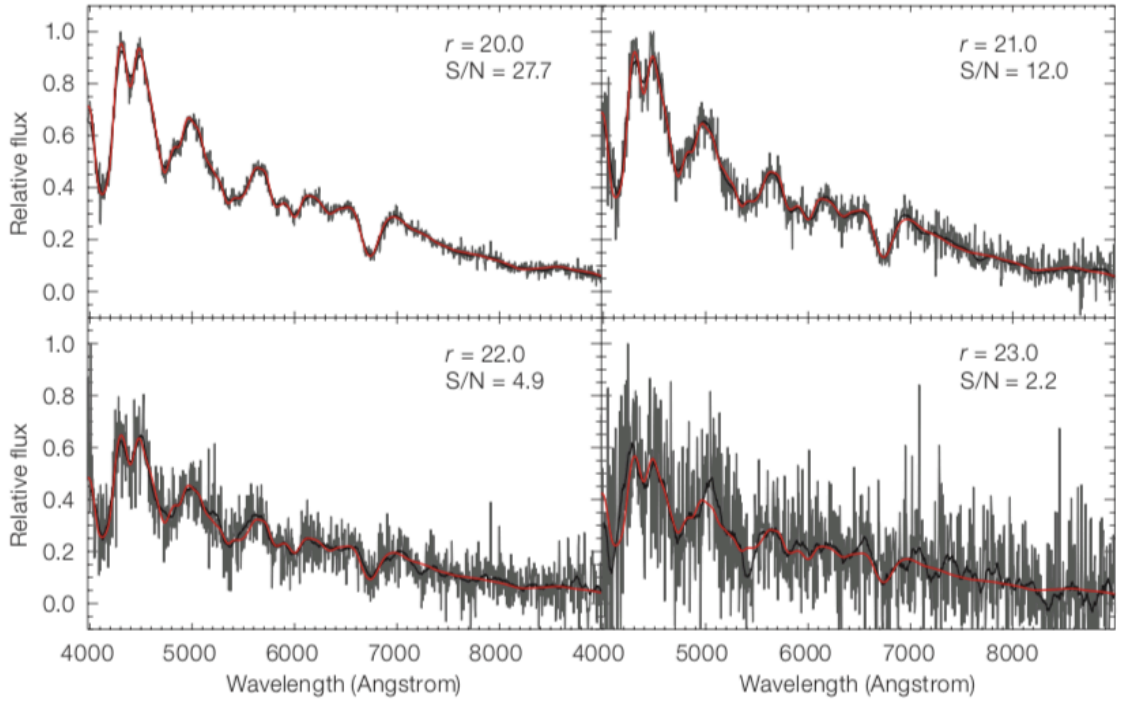
This work

Jon Carrick

- Main science goal: Type Ia SN cosmology
- How should we use 4MOST to create the best possible training sample for photometric classification?
- For now, we are considering the final classification, not early classification for triggering follow-up

Capabilities of 4MOST

- Fixed exposure time:
  - TiDES has 250,000 fibre-hours
  - Baseline 120 min per field visit
  - Longer in 4MOST deep fields
- A 4MOST-only training sample will be magnitude limited to r(AB) ~22.5 mag

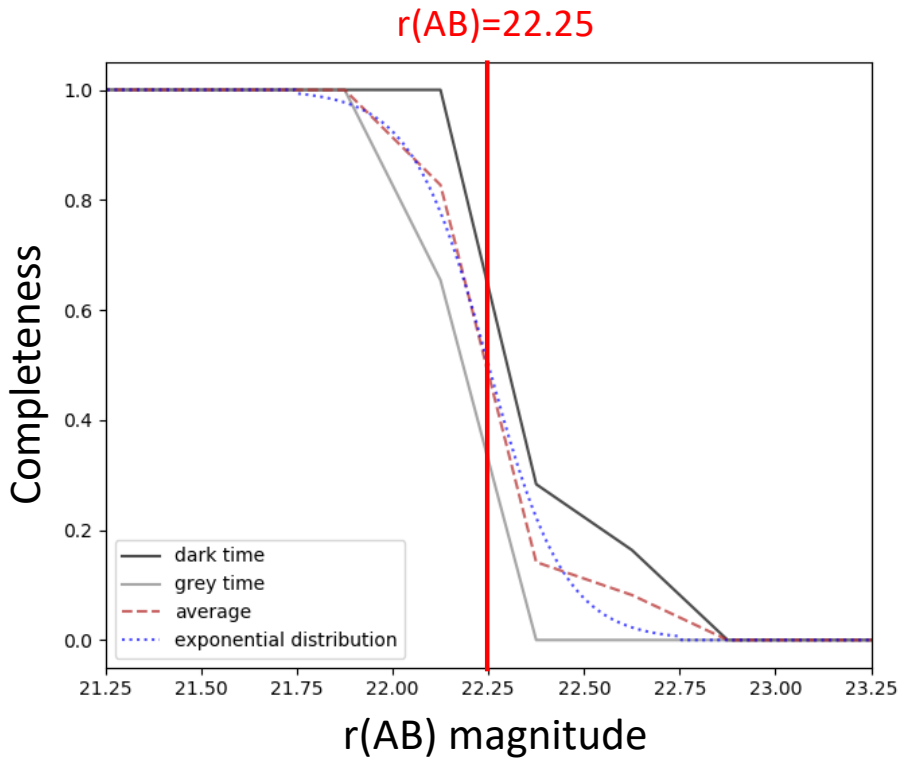


Typical spectra in one hour of exposure, Swann et al 2019

TiDES spectral success rate

Completeness =
Success rate *for those transients attempted*

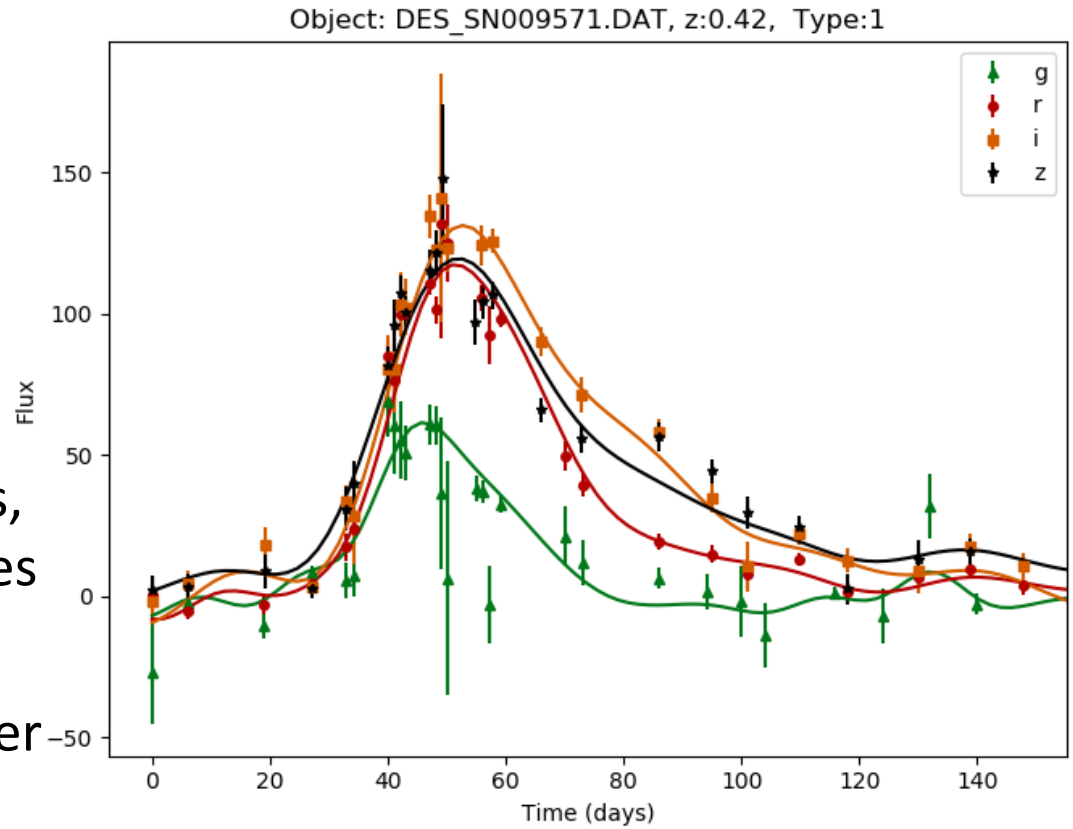
Success defined as
S/N> 10 per 15A bin,
averaged over
4500 - 8000 A



From the 20/5/19 4MOST Exposure Time Calculator run

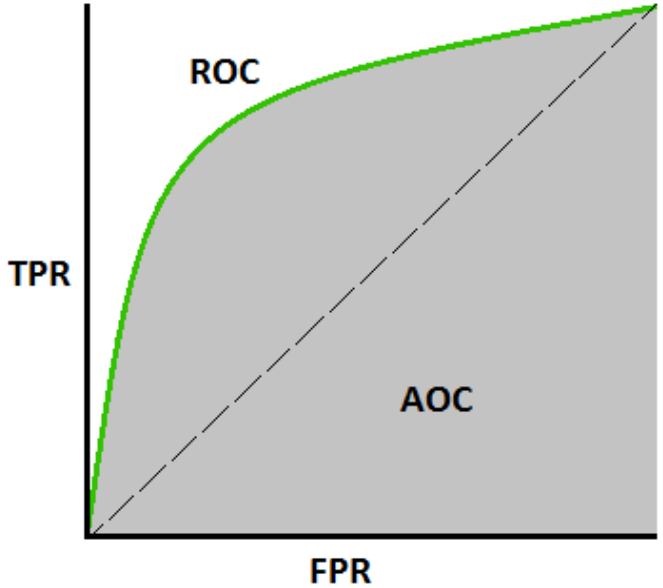
Classification method

- *snmachine* (Lochner et al. 2016)
- Using wavelets feature extraction
- Supernova Photometric Classification Challenge (SPCC) data.
- 21,000 objects with DES-like lightcurves, 1103 training objects with known classes
- Future: PLAsTiCC with new version of *snmachine* (late 2019?) + hopefully other classifiers to compare performance



SPCC Type Ia SN light curve fit with wavelets

Method

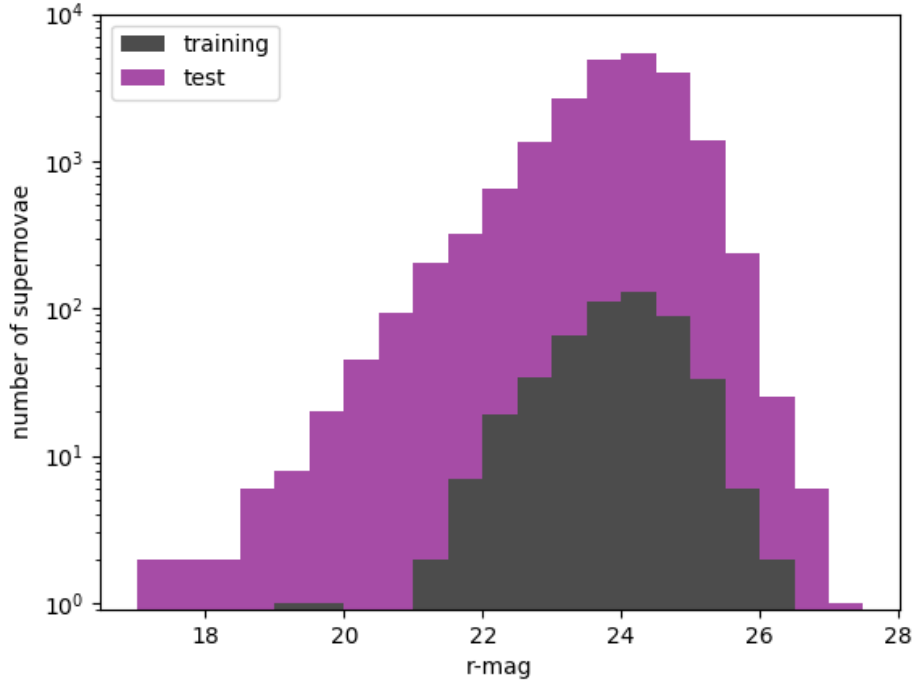


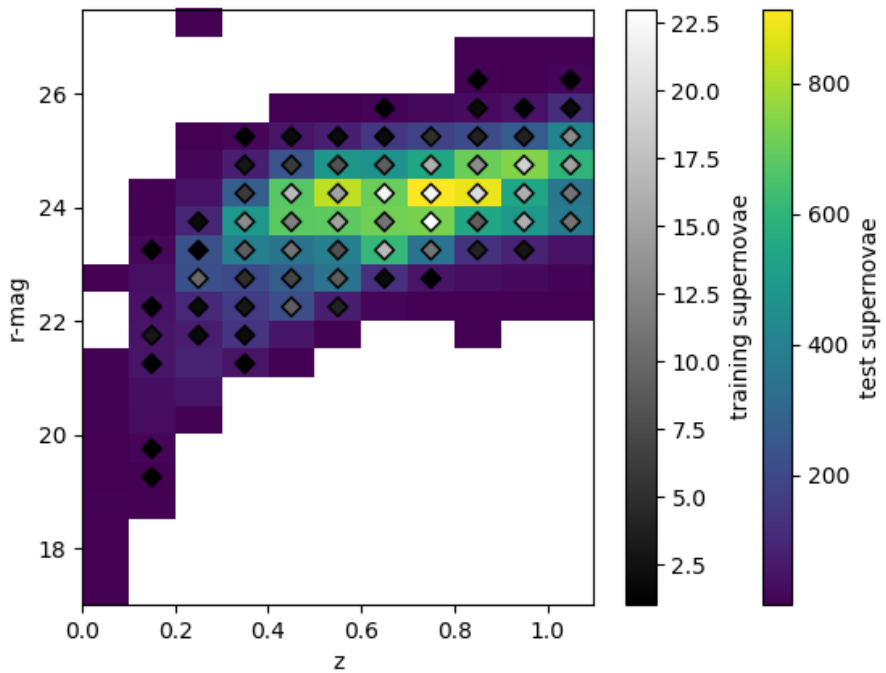
- Different training samples selected based on…
  - Magnitude limit, class balance, extra faint objects (from another telescope or data augmentation)
- Metric: ROC curves and area under Curve (AUC)
  - general performance of classifier for binary classification of Ia vs CC
- We used “spectroscopic z” throughout
  - Assumes that for Ia Hubble diagram, objects have at least a host spectrum

Representative training sample

- 500 training objects selected randomly (class and magnitude representative)

Note log(N) scale





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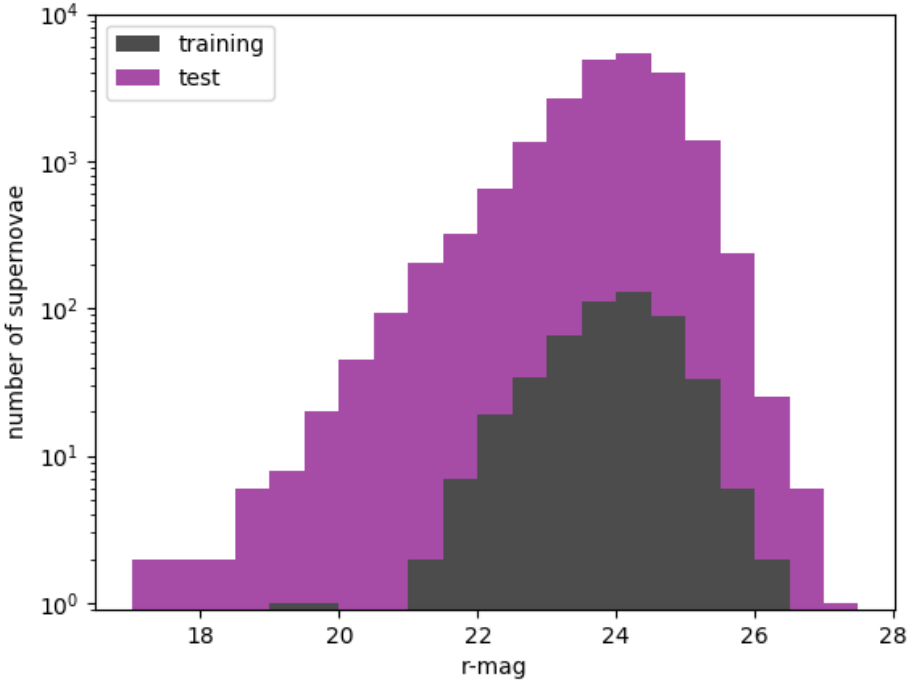
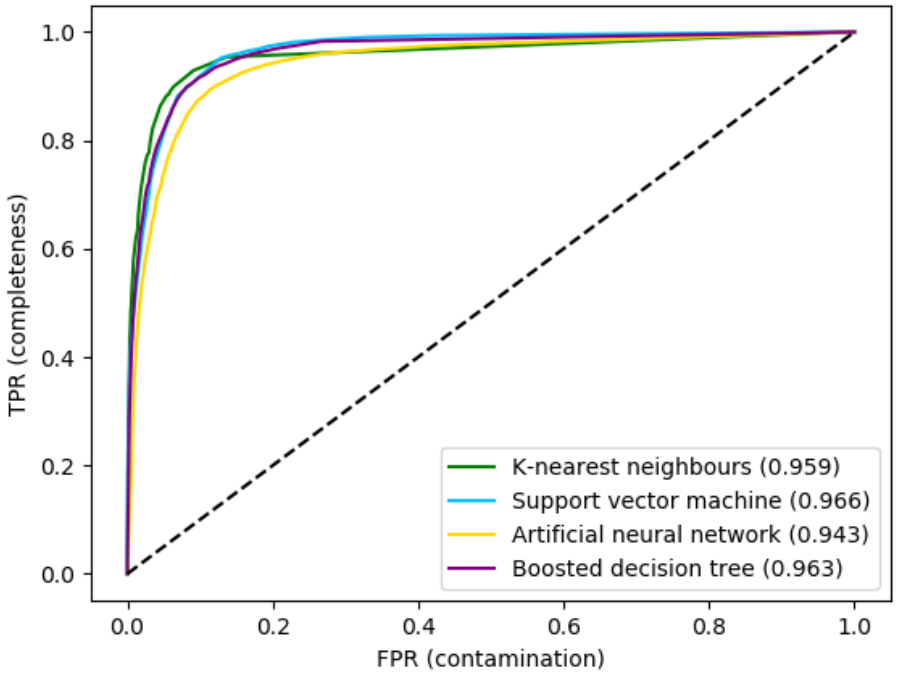


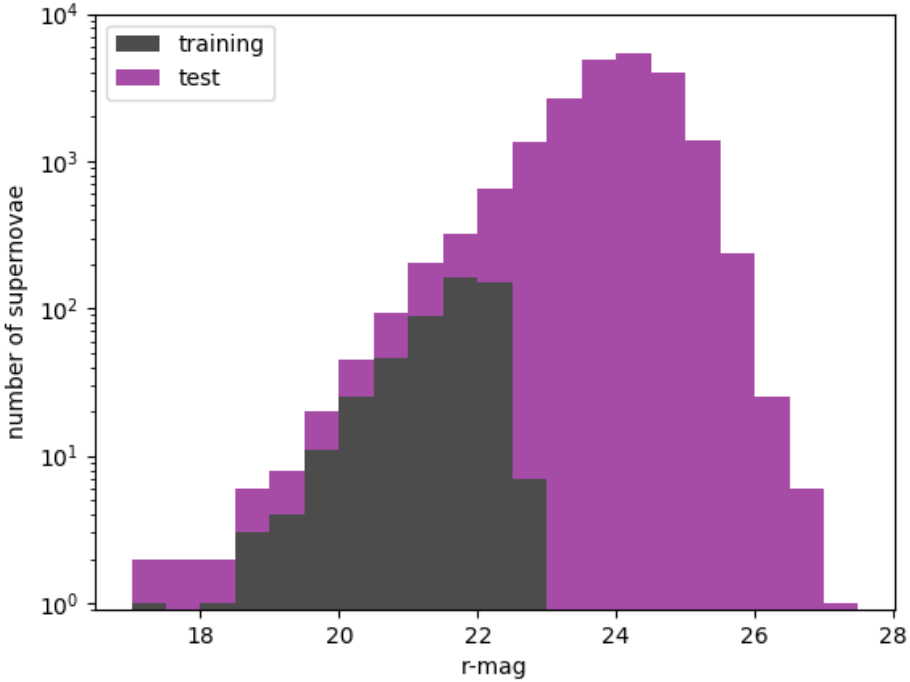


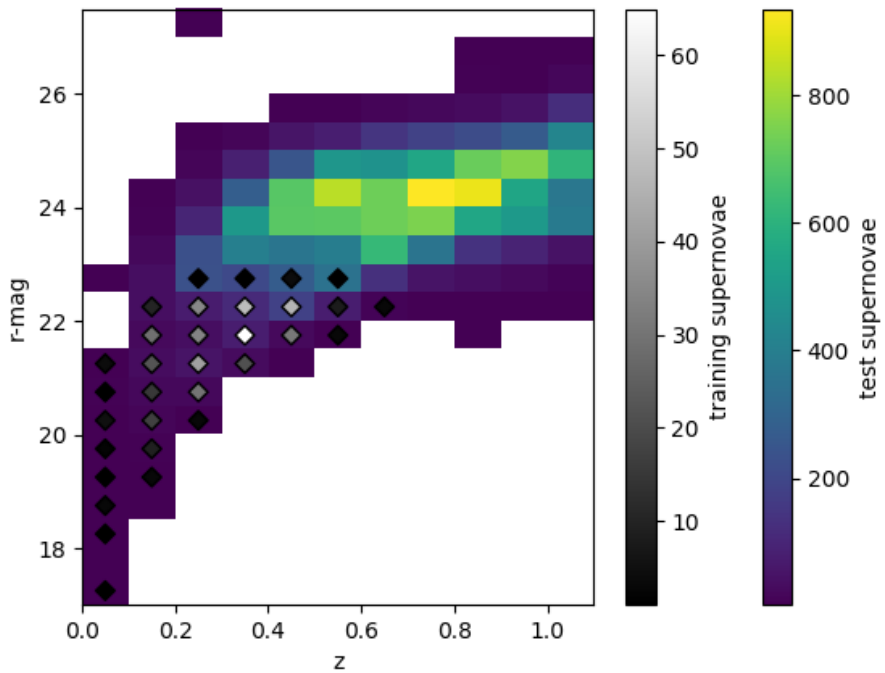
Mean AUC for 1103 training objects = 0.958

Mean AUC for 500 objects = 0.943

Magnitude-limited training sample

- 500 training objects sampled randomly following spectral completeness curve with 50% max





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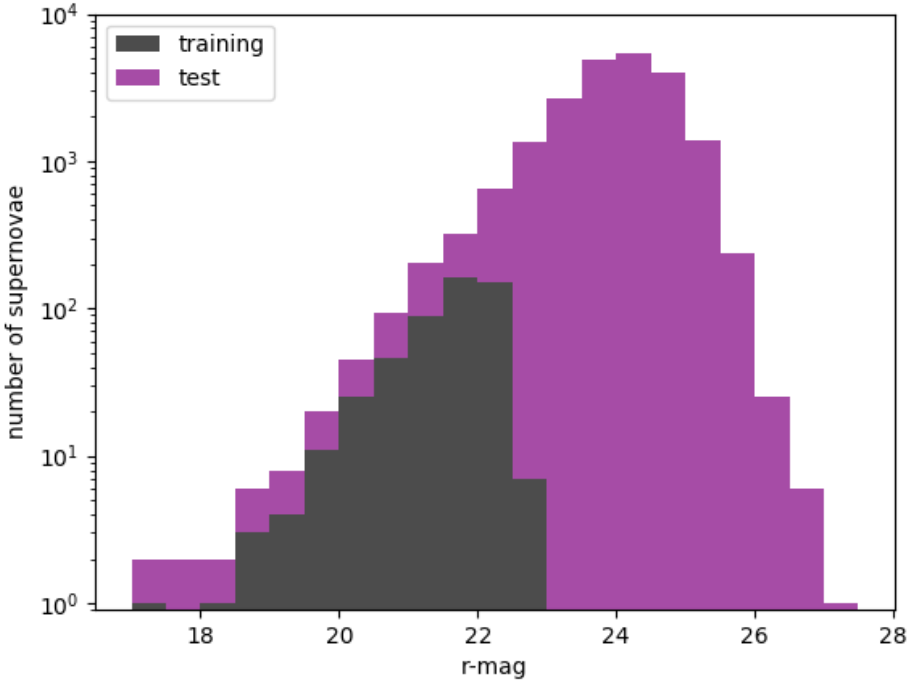
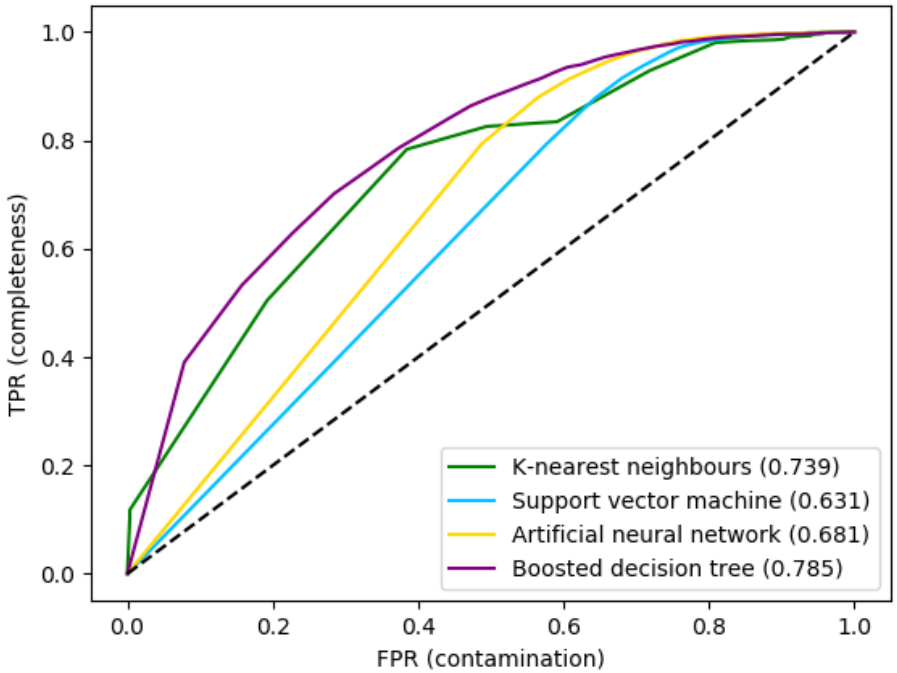


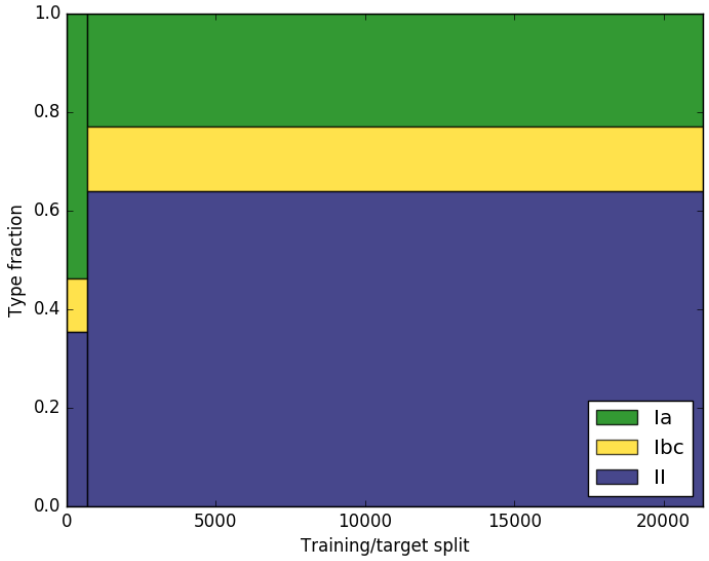


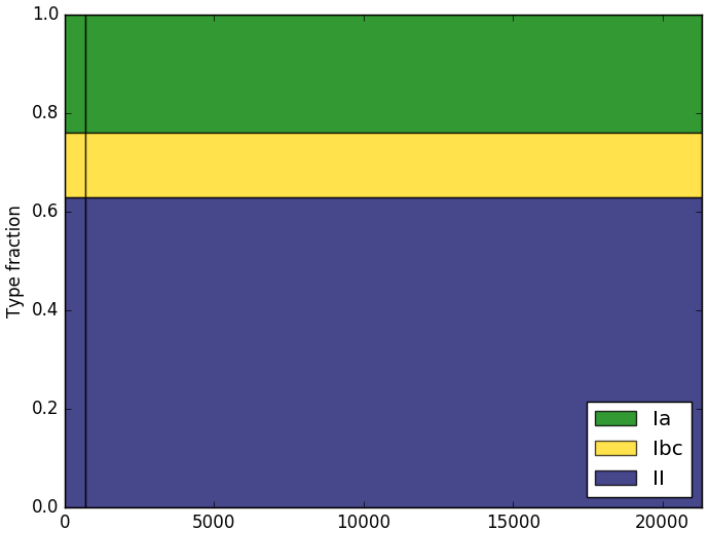
AUC average = 0.709

Balancing classes

- A magnitude-limited sample is not balanced in terms of classes
- Can create a magnitude limited, class-balanced set
  - Proportions of three classes forced to match the test set
  - Kept total number of training objects the same

Classes not balanced

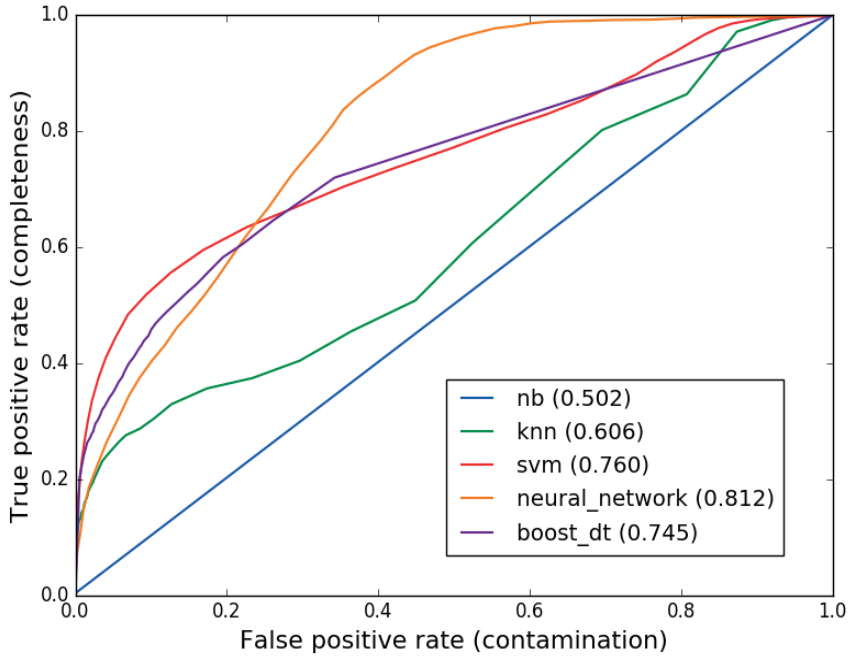




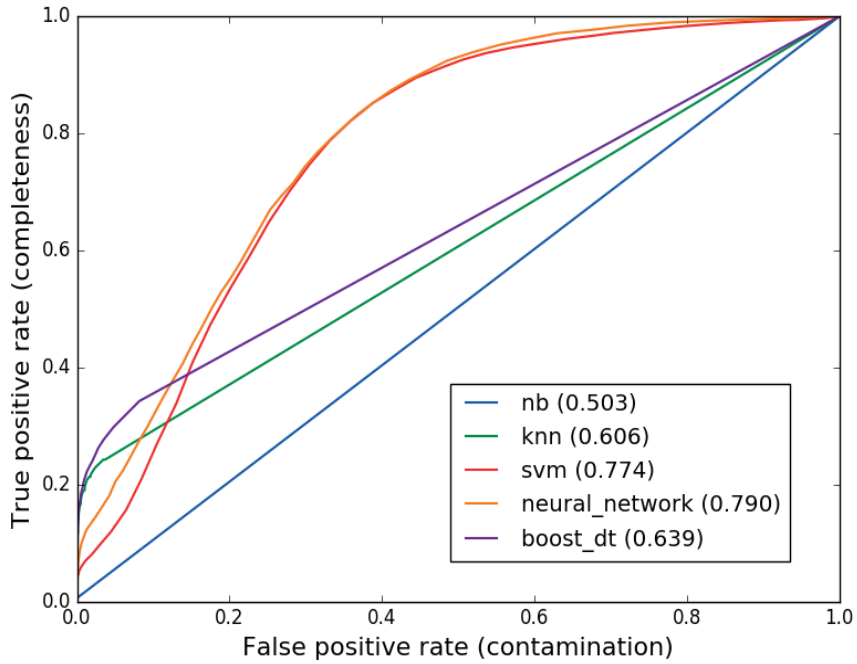
Classes balanced

Magnitude-limited training sample (r < 22.5)

Classes not balanced



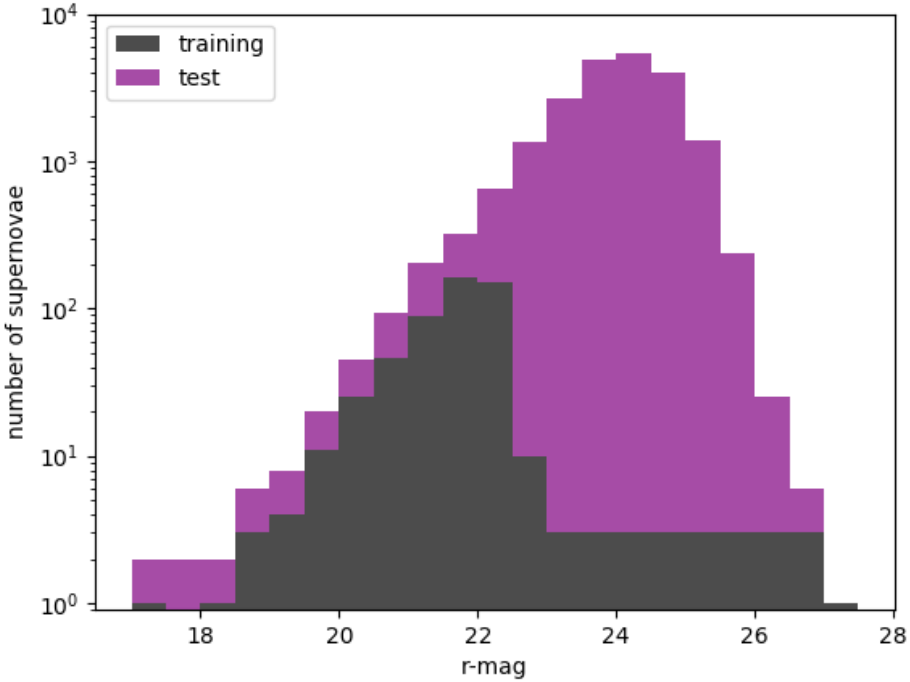
Classes balanced

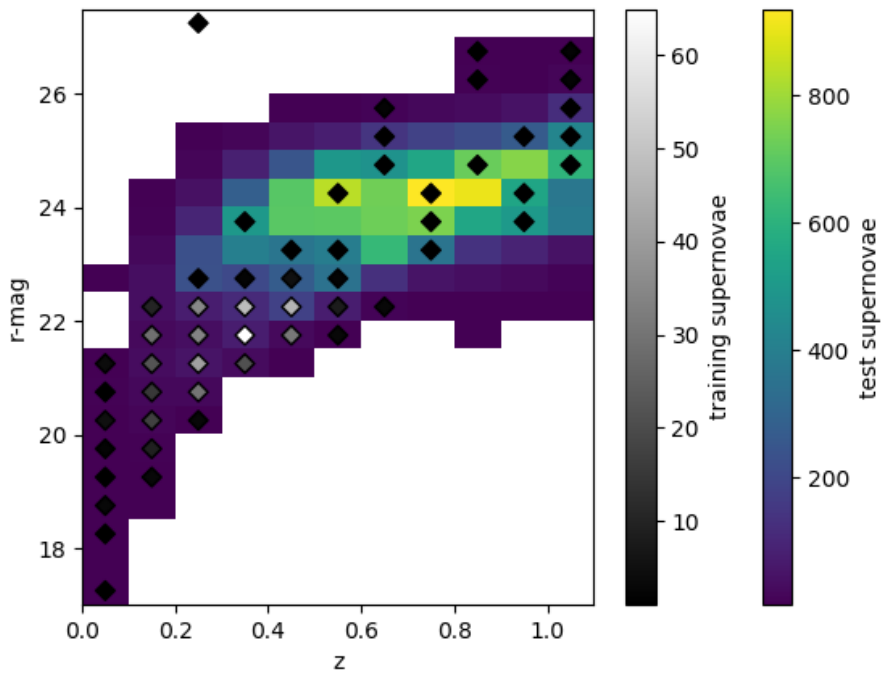


Conclusion – balancing classes doesn't help much. Magnitude limit affects the performance.

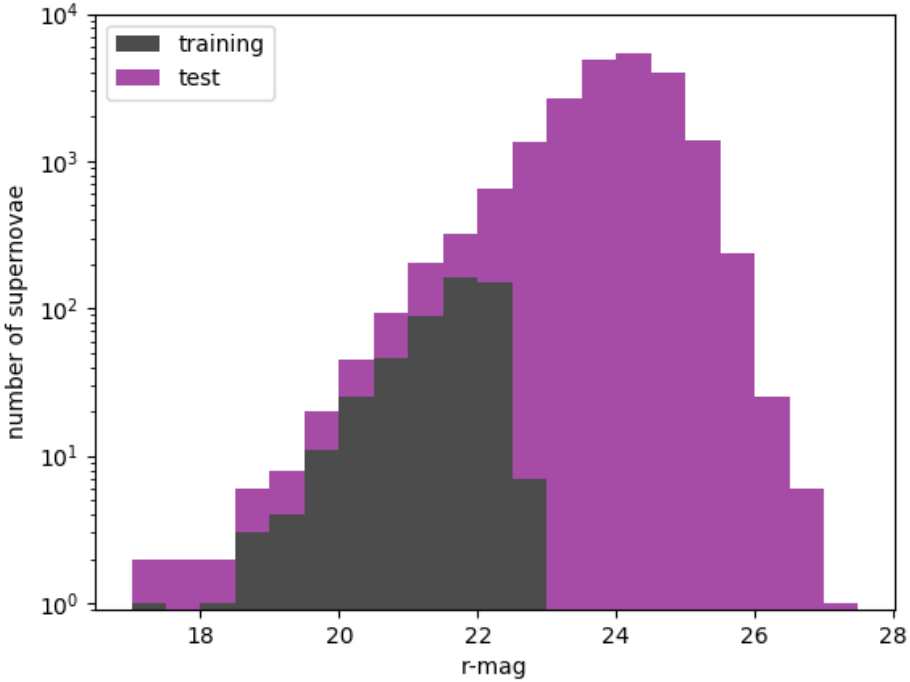
Adding fainter objects

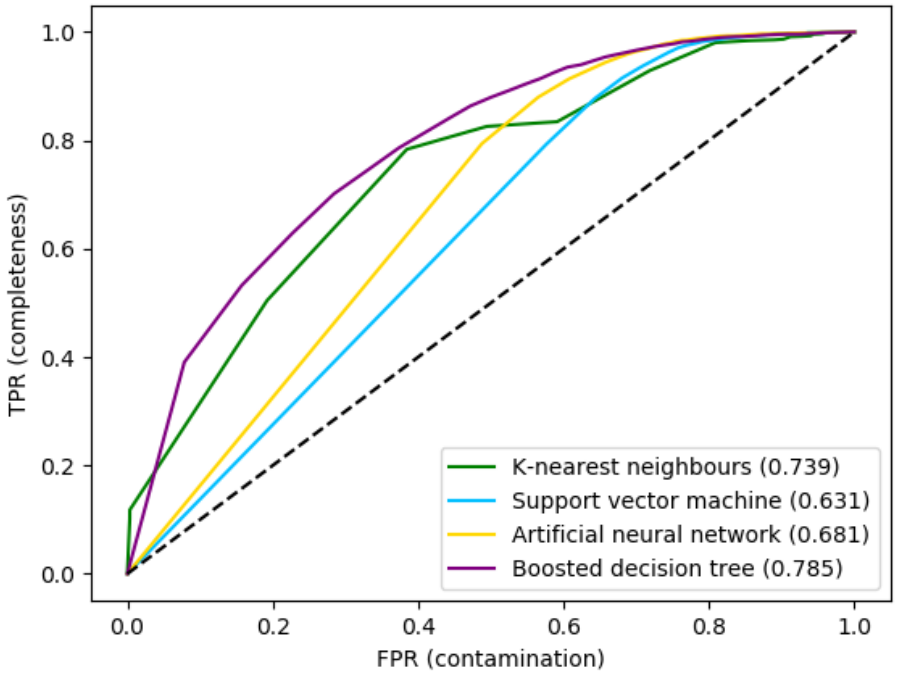
- Adding one extra supernovae per type (Ia, Ibc, II) per 0.5 magnitude bin – 30 total





Adding fainter objects – results before

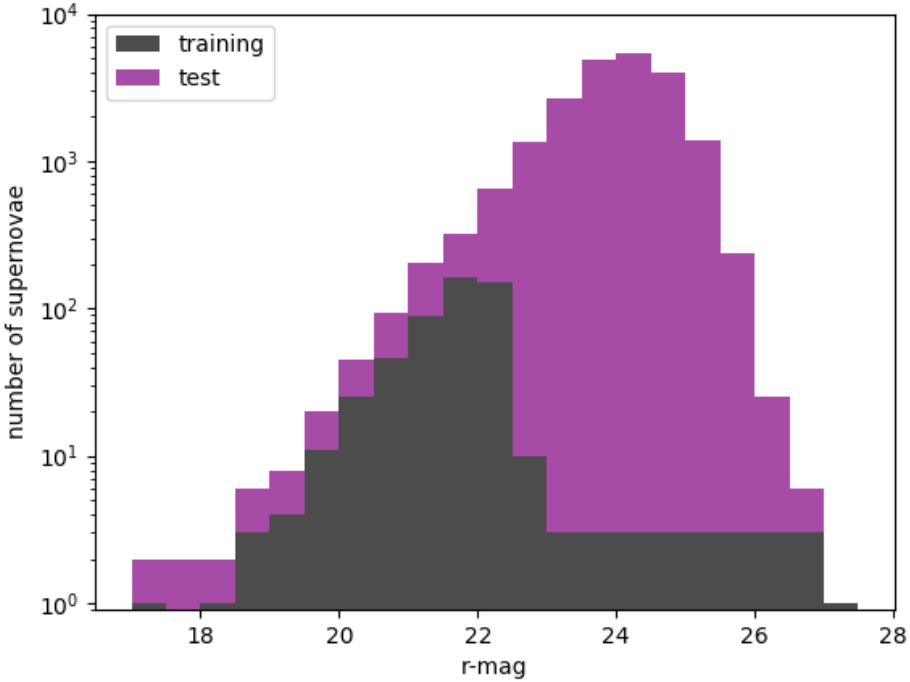


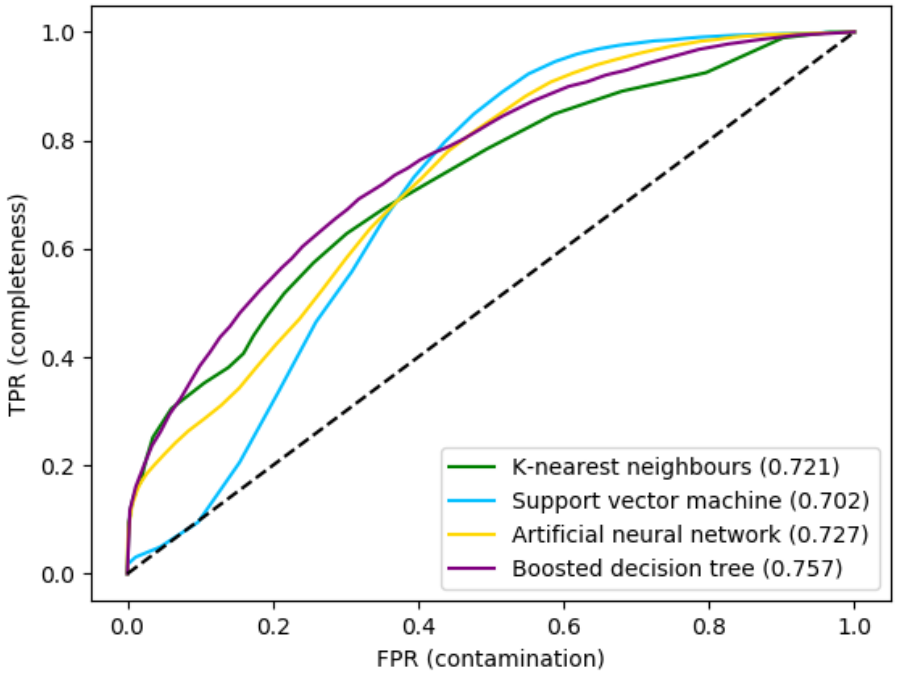


AUC average = 0.709

Adding fainter objects – results after

fainter training objects added





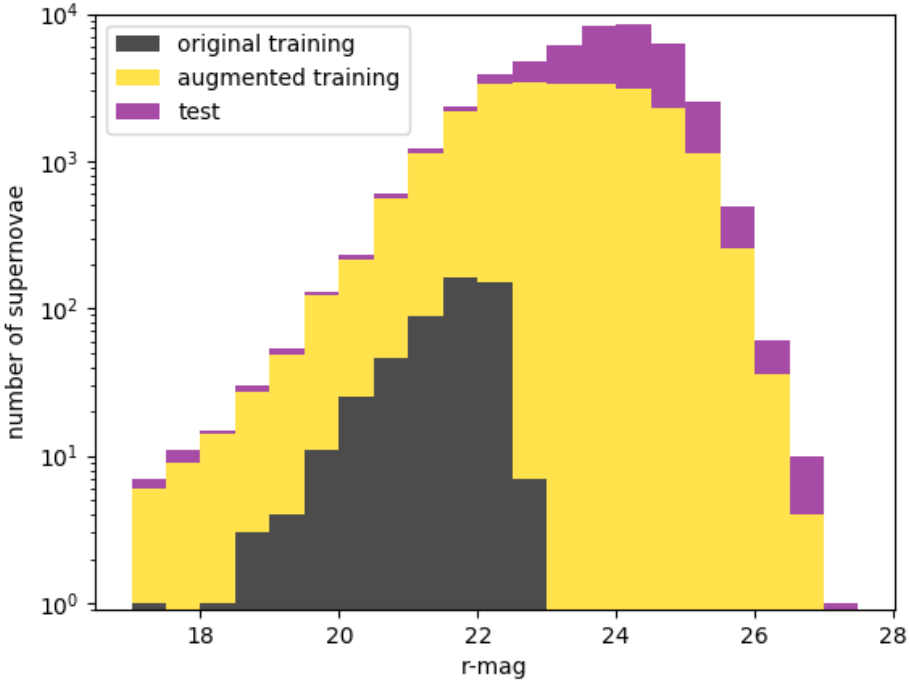
AUC average = 0.727

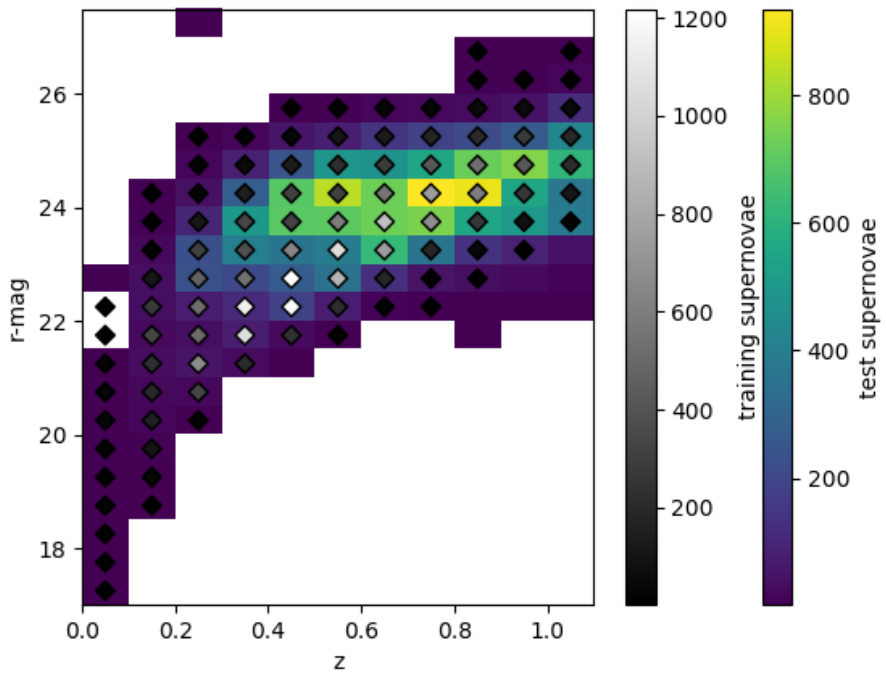
Adding fainter objects

- Adding a few faint objects helps a bit
  - Depends on algorithm and on the exact set of objects chosen.
- But also implies longer exposure times (not easy with 4MOST) or using different spectroscopic facilities
- Try data augmentation (preliminary)
  - Using Avocado method (Boone 2019)
  - Resamples training lightcurves at new redshift (redshifted bandpasses), dims by DM and adds noise(*)

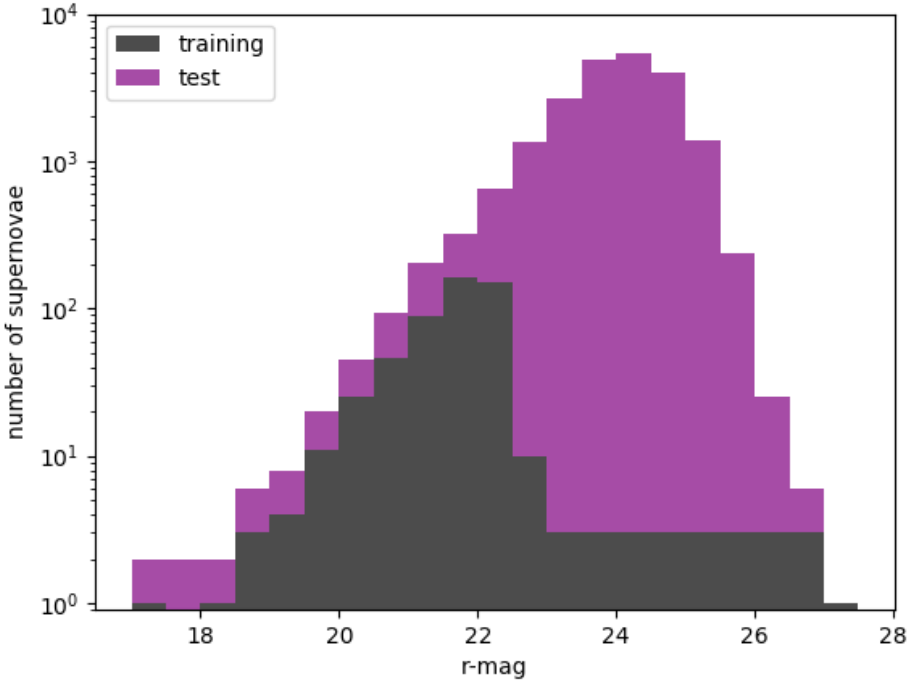
Data augmentation (preliminary)

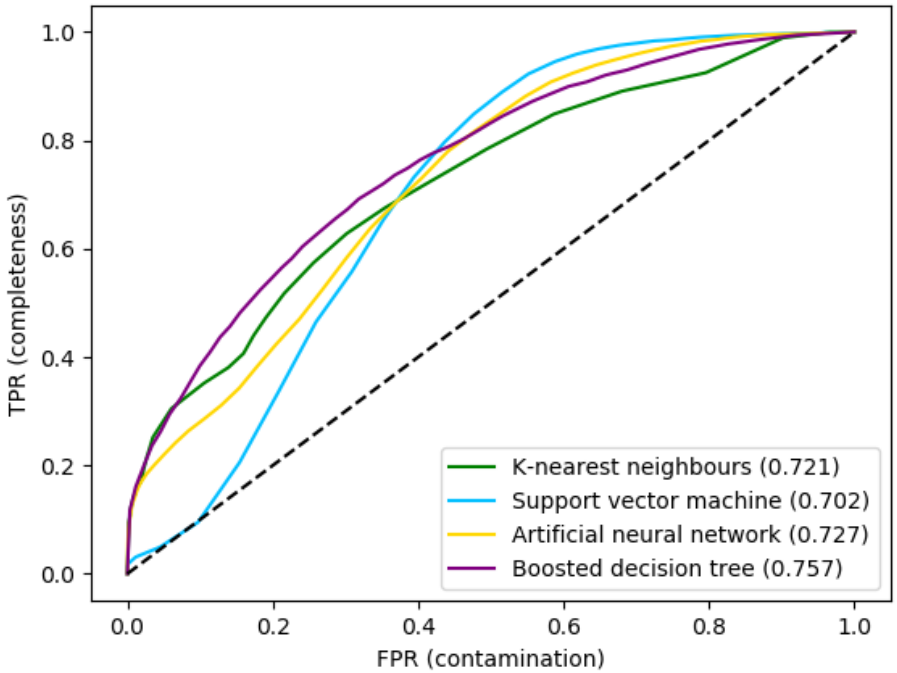
- Training data augmented x50, and extends to higher redshift





Adding fainter objects – results after





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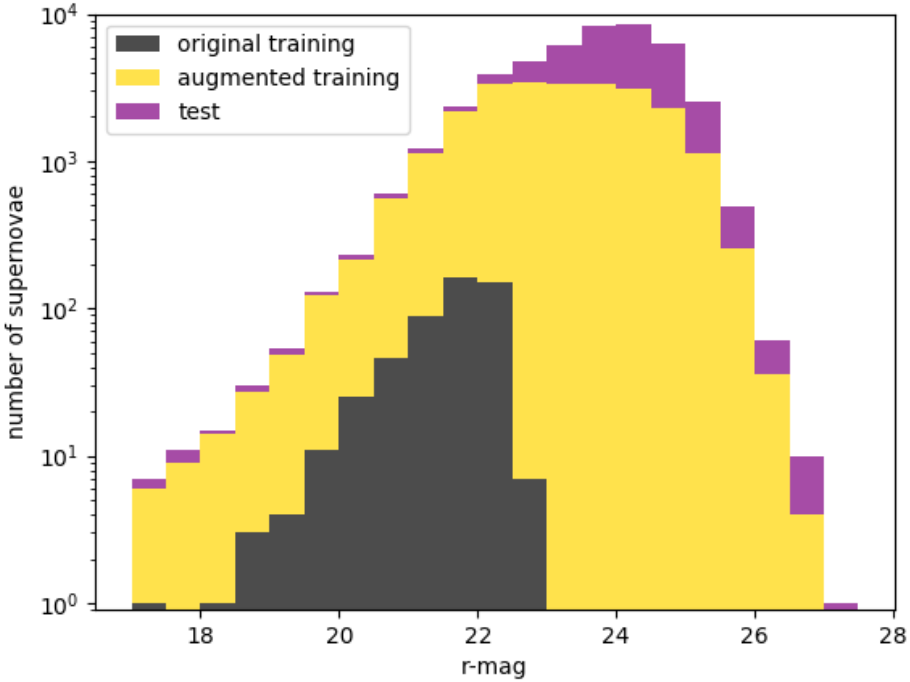
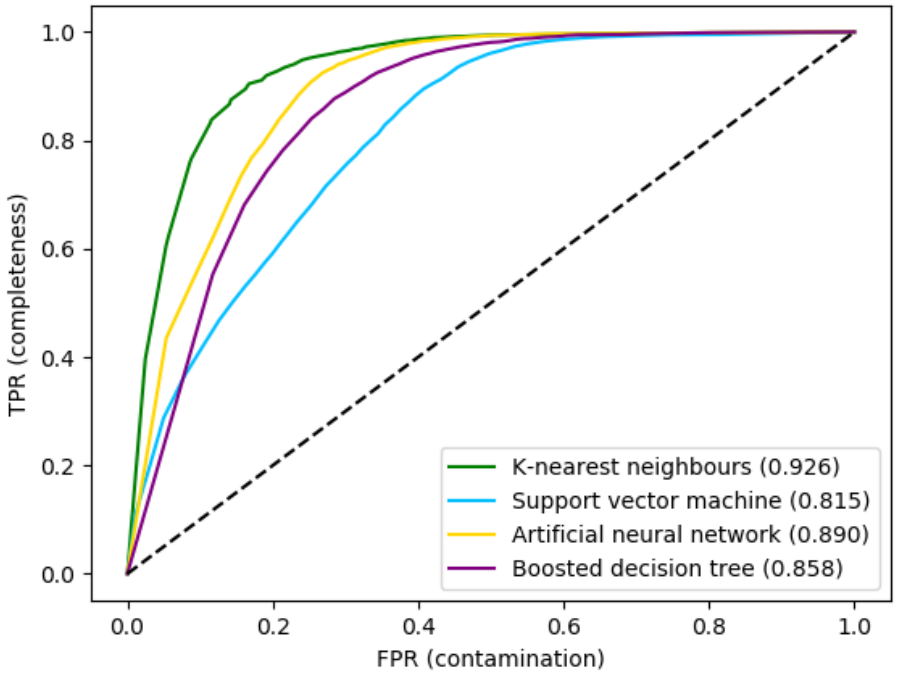
Data augmentation – results after





AUC average = 0.872

Results summary

Training sample type	N training	4MOST exp time / 10^6 s	Mean AUC	
Representative	500	343.4	0.943	average of 5 runs
Mag limited	498	7.9	0.709	one run
Faint added	526	147.3	0.727	one run
Augmented	498 (aug. to 24636)	7.9	0.872	one run

Preliminary conclusion:
Data augmentation very promising but doesn't capture everything
(Also potential biases)

Conclusions

- 4MOST-TiDES will accumulate the largest spectroscopically-confirmed Ia sample for cosmology to date
- The live transient sample will also act as a training sample for photometric classification of other LSST transients, but with a magnitude limit that affects performance
- To address this, we must either reallocate exposure time, or make use of other spectroscopic facilities, or consider data augmentation methods
- …or accept a reduced sample size
- Paper in preparation (Carrick et al)