

Photometric Classification of the HSC Transients through Machine Learning

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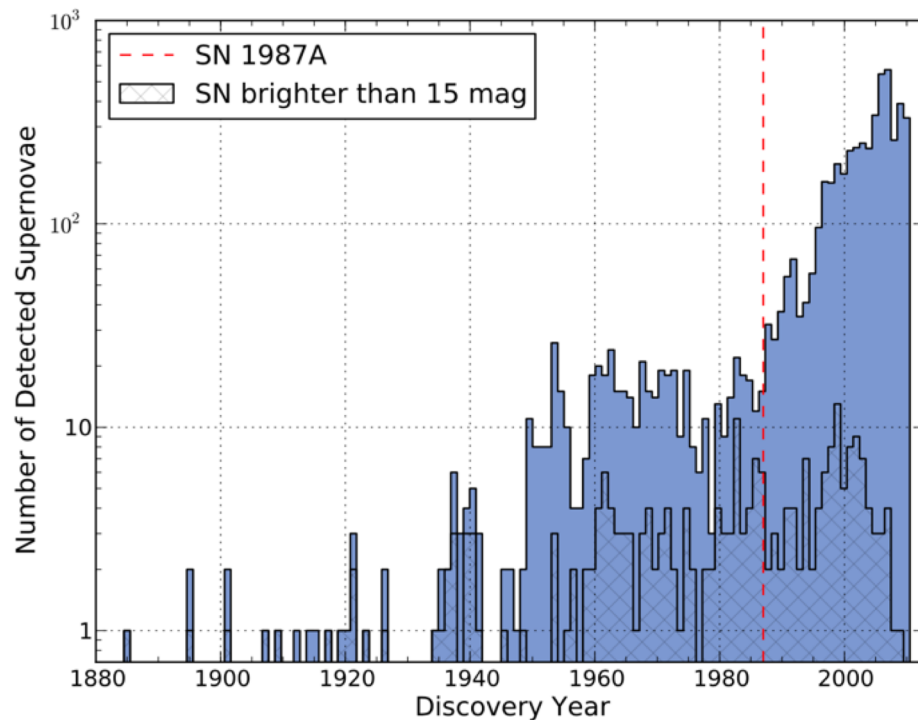
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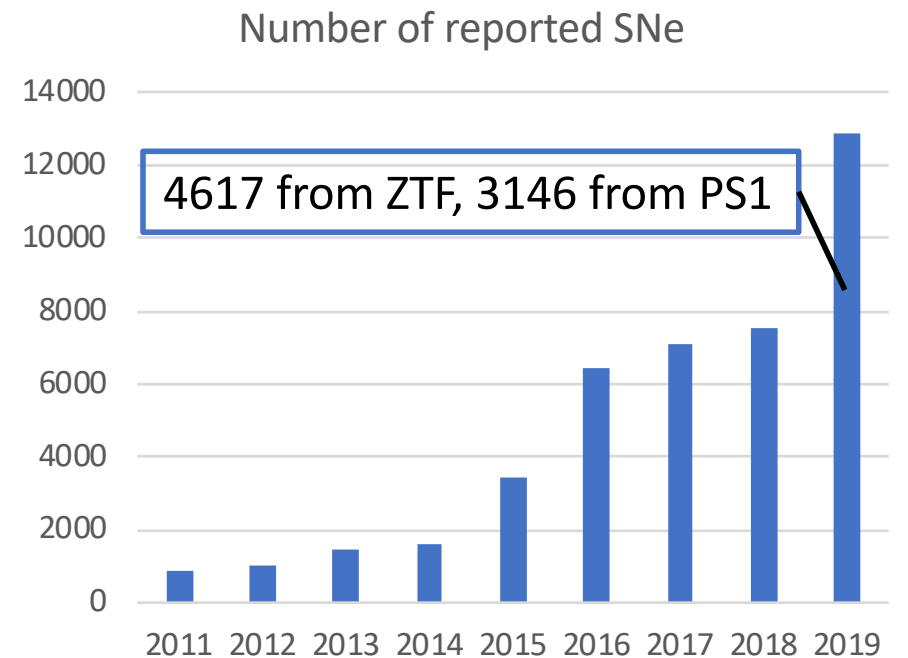


Increase of discovered supernovae

In recent years, The number of discovered supernovae has been rapidly increasing because of advances in observation technology.



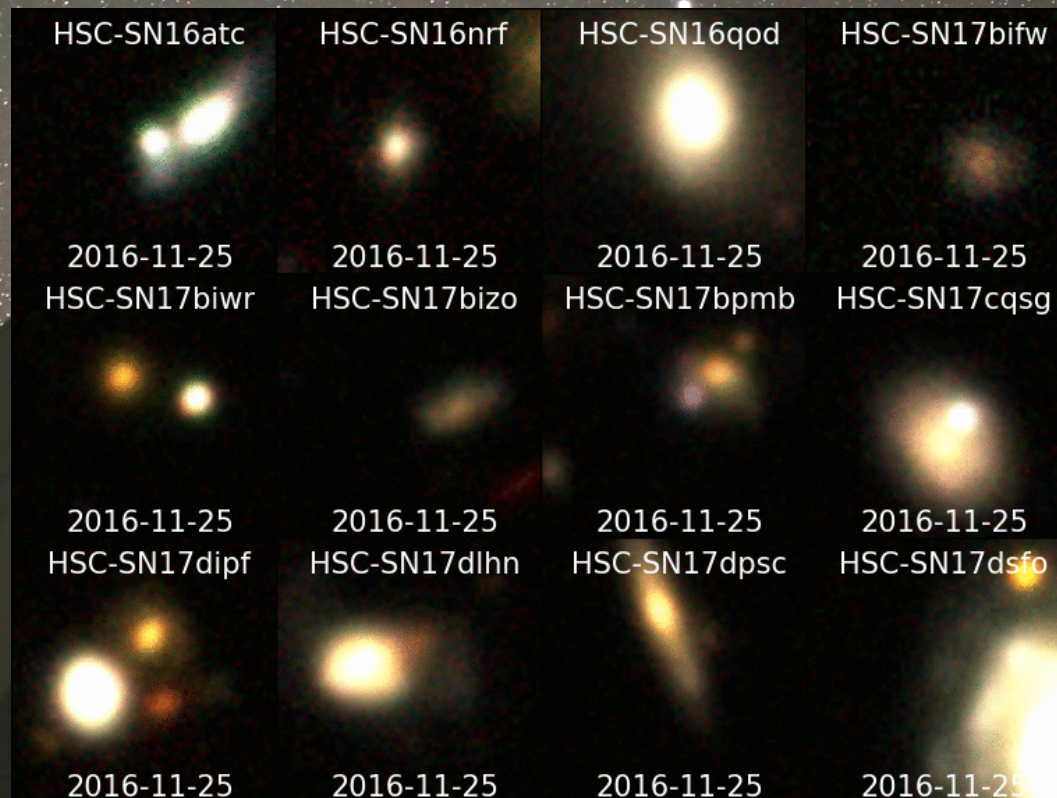
D. Lennarz et al. 2011



from ASRAS web

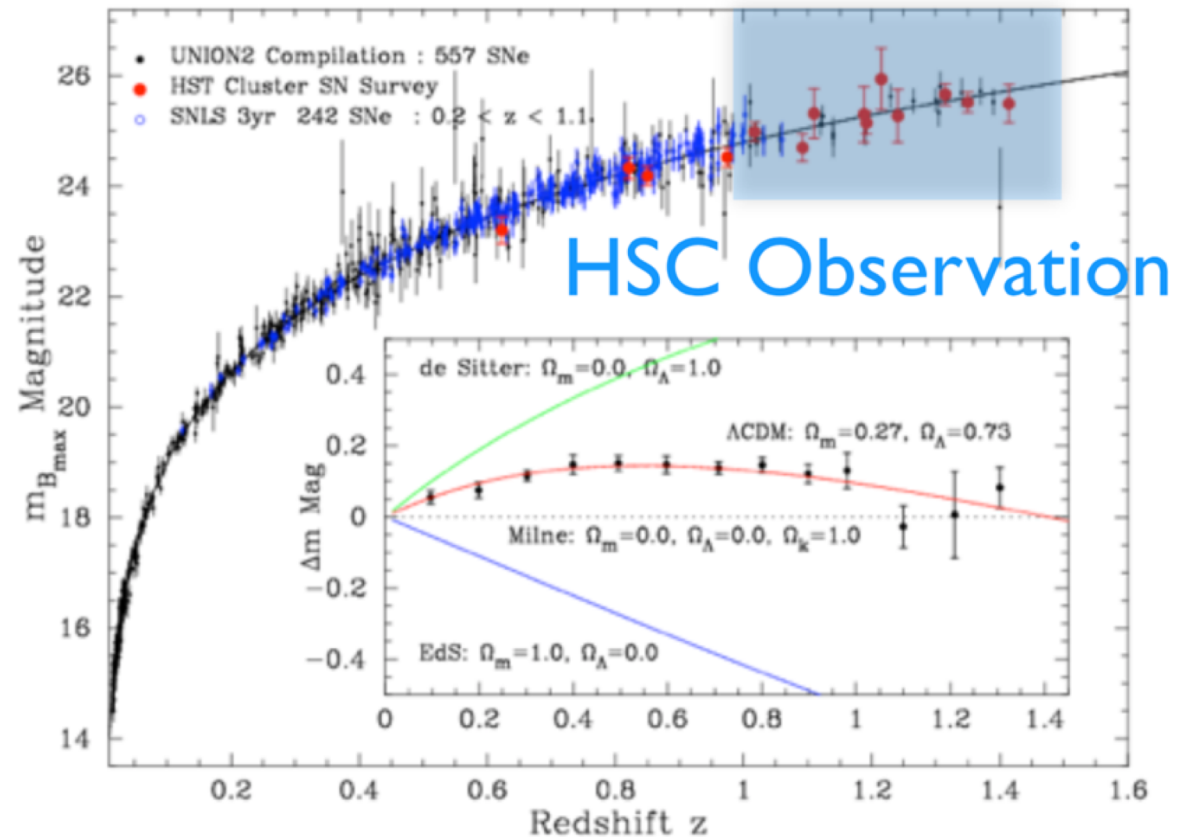
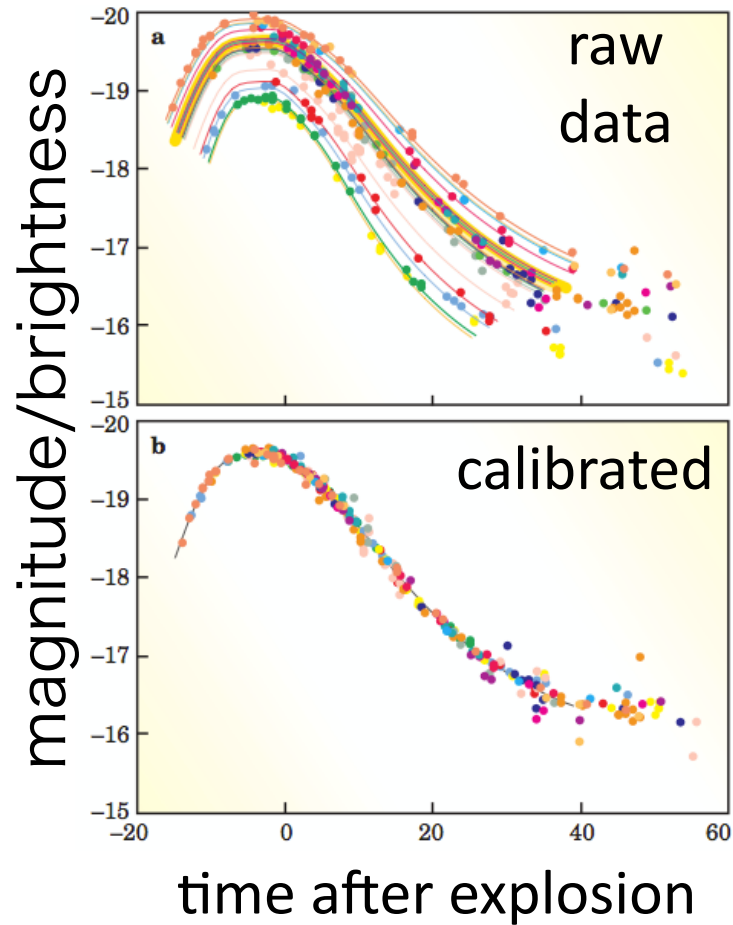
- The Dark Energy Survey (DES, Ongoing) : $\sim 3,000$ SNIa over 5 years
- Large Synoptic Survey Telescope (LSST) : $\sim 10^5$ SNIa each year

HSC SSP Transient Survey in COSMOS 2016 – 2017



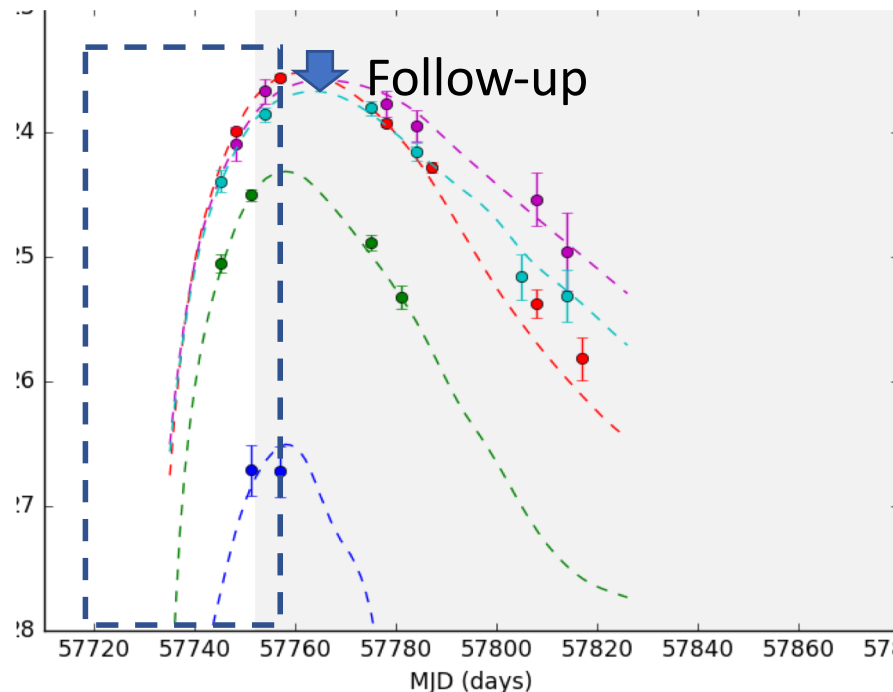
- Overview : Yasuda et al. 2019
- 6 months from Nov. 2016
- 52 times obs. (g, r, i, z, Y)
- 1824 active SNe
 - 58 objects at $z > 1$
- Follow-up observation :
Keck/VLT/Gemini/HST

SN Ia Cosmology using Subaru/HSC



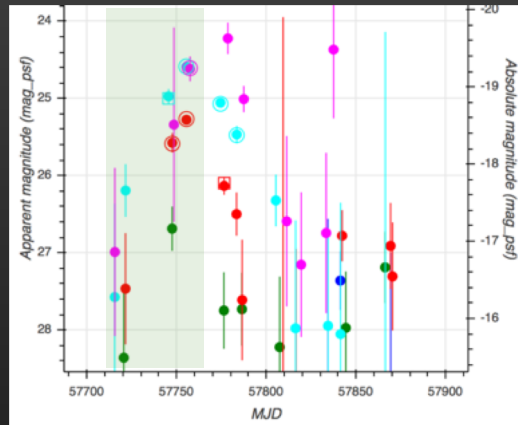
Supernova type classification

- Many detected supernova (100 newly in several week for HSC)
- We need to select follow-up targets quickly and accurately
 - Multiple types of supernovae -> only type Ia
 - Follow-up at the peak
- We developed a classifier using machine learning

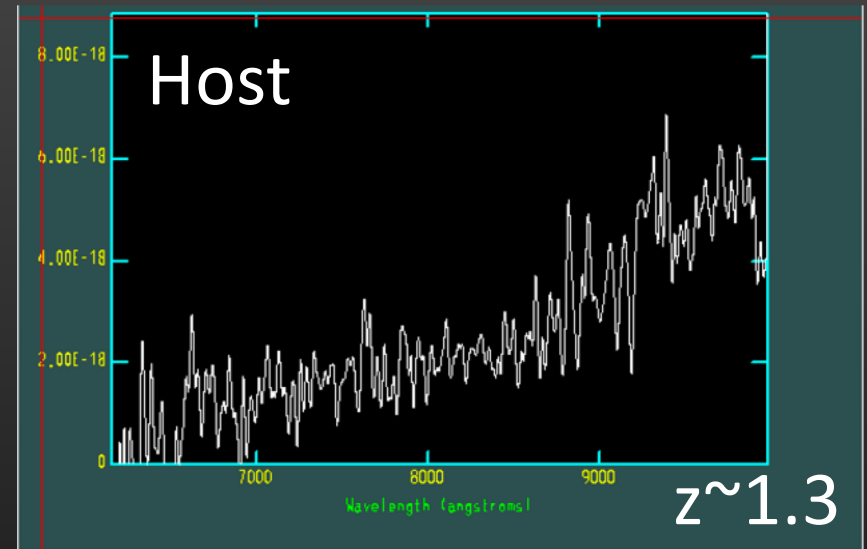


Follow-up Observation

SN aqzh (Ia, Ia prediction : 0.918)



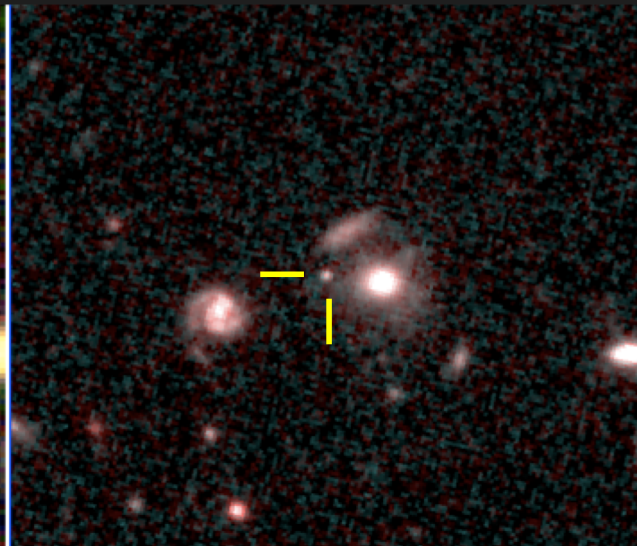
Subaru/FOCAS Spectrum



Subaru/HSC (Optical)



Hubble Space Telescope (IR)

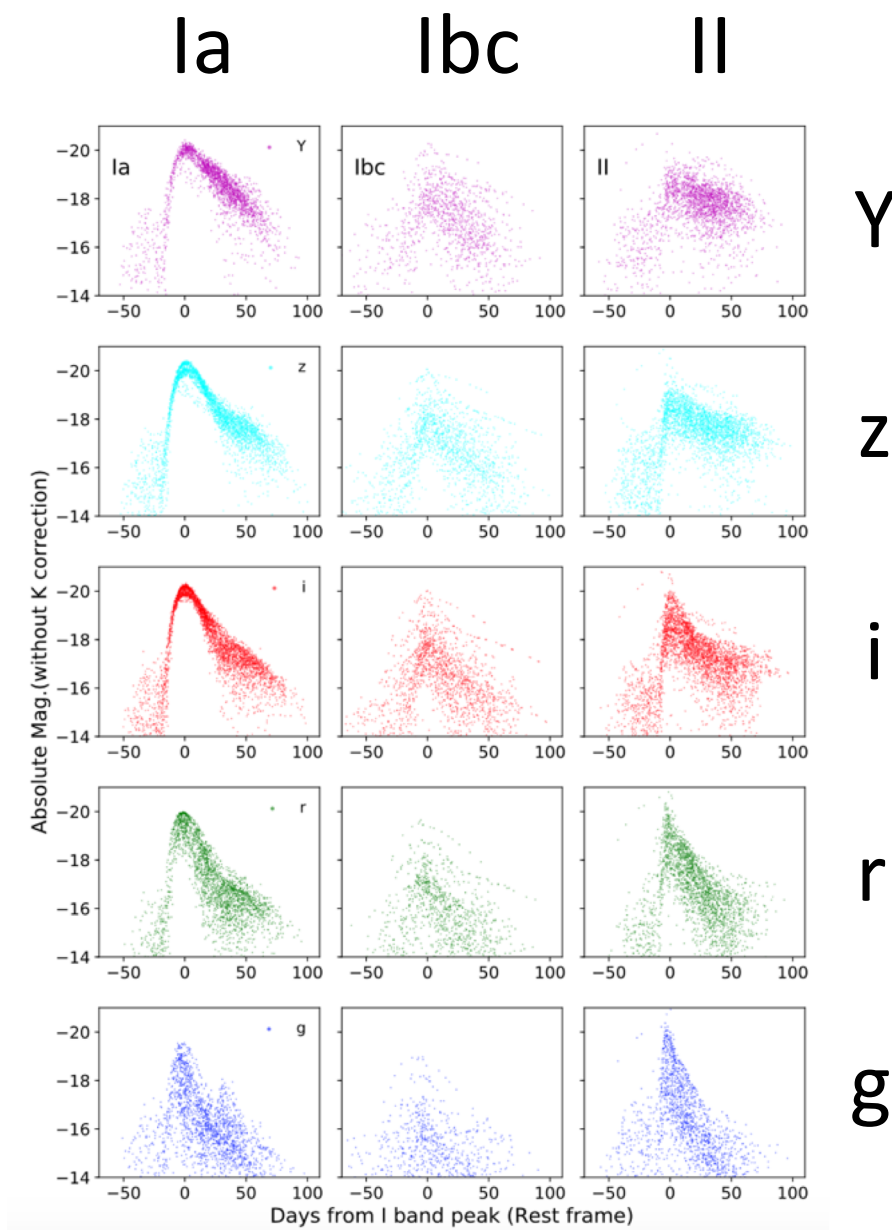


Improvement of classifier

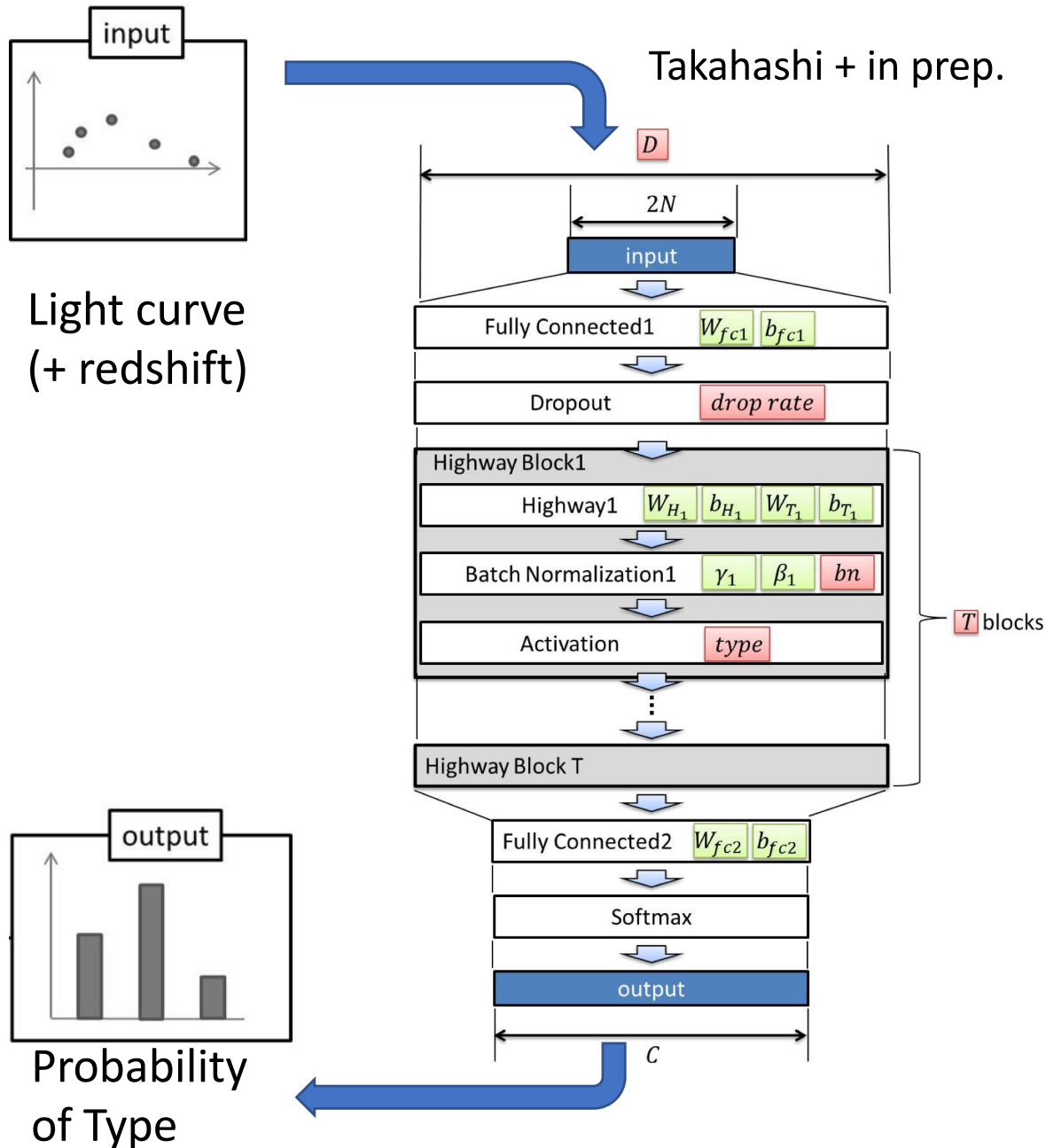
- Preparing for the next survey
- Multi-class classification(Ia, Ibc, II)
- Validation using **PLAsTiCC** data
 - Photometric **L**SST **A**stronomical **T**ime-Series **C**lassification Challenge
 - Competition @ Kaggle: Sep. 28 – Dec. 17, 2018
 - Test data : 3.5 million samples, Training data : 8000
 - 15 class (SNe, AGN, variables, micro-lensing)
- Apply to HSC transient survey 2016 data

Create learning dataset

- Hundreds of thousands of simulated light curves
- Using SNANA and PLAsTiCC templates
- Ia, Ibc and Type II



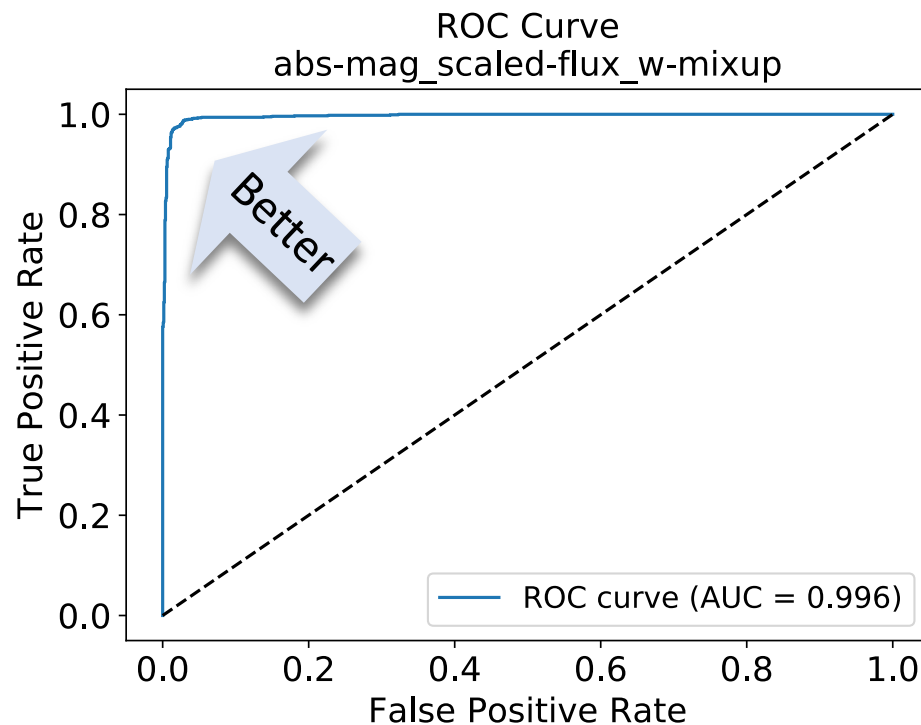
Classifier



- DNN
- Input photometric data directly
- Output probability of each type
- Only for fixed observation schedule
- Use DDF for PLAsTiCC data validation

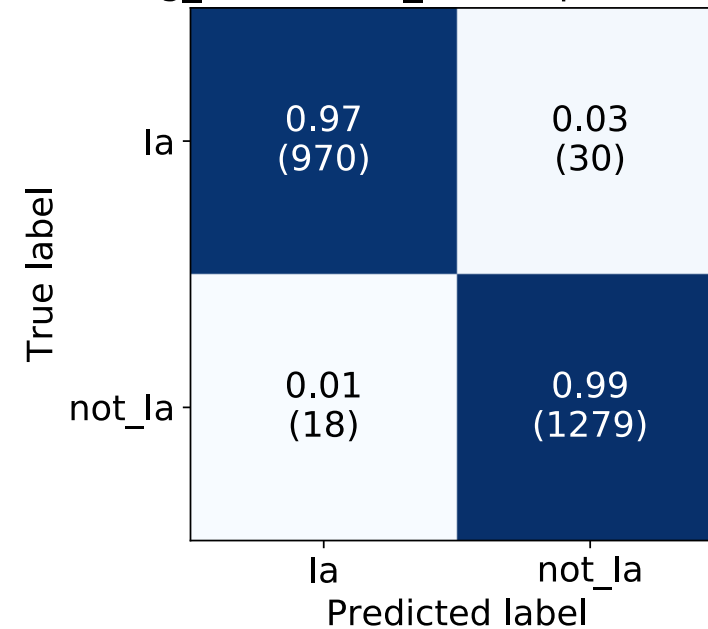
Validation using PLAsTiCC DDF data

2 class AUCs



2 class Confusion Matrix

Normalized confusion matrixn,
abs-mag_scaled-flux_w-mixup, accuracy:0.979

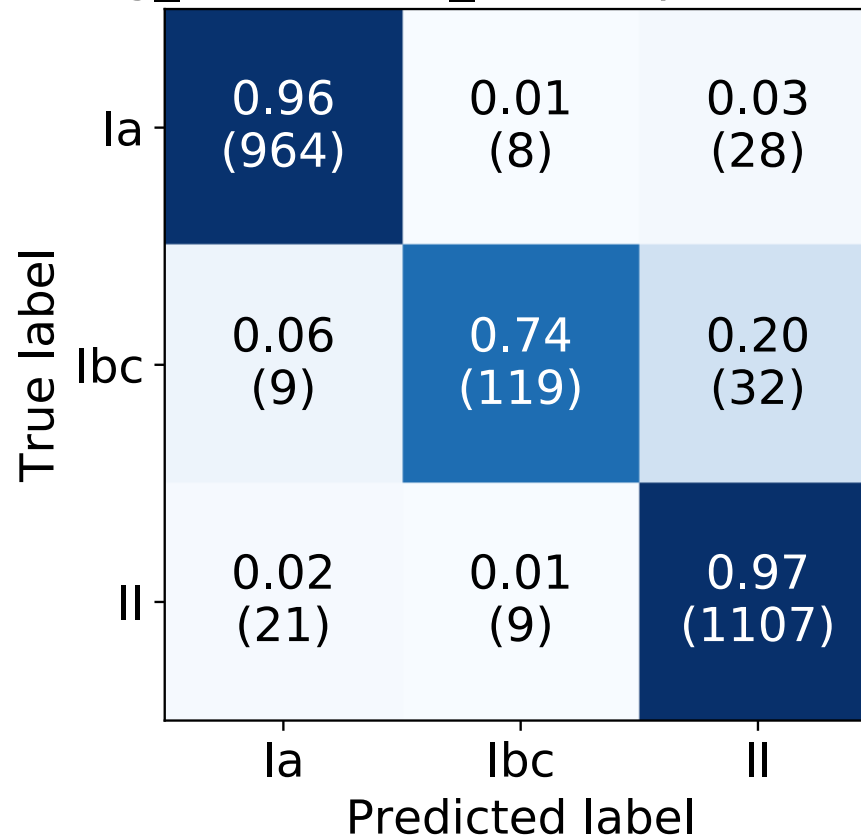


Kappa coefficient : 0.957

Validation using PLAsTiCC DDF data

3 class Confusion Matrix

Normalized confusion matrixn,
abs-mag_scaled-flux_w-mixup, accuracy:0.953



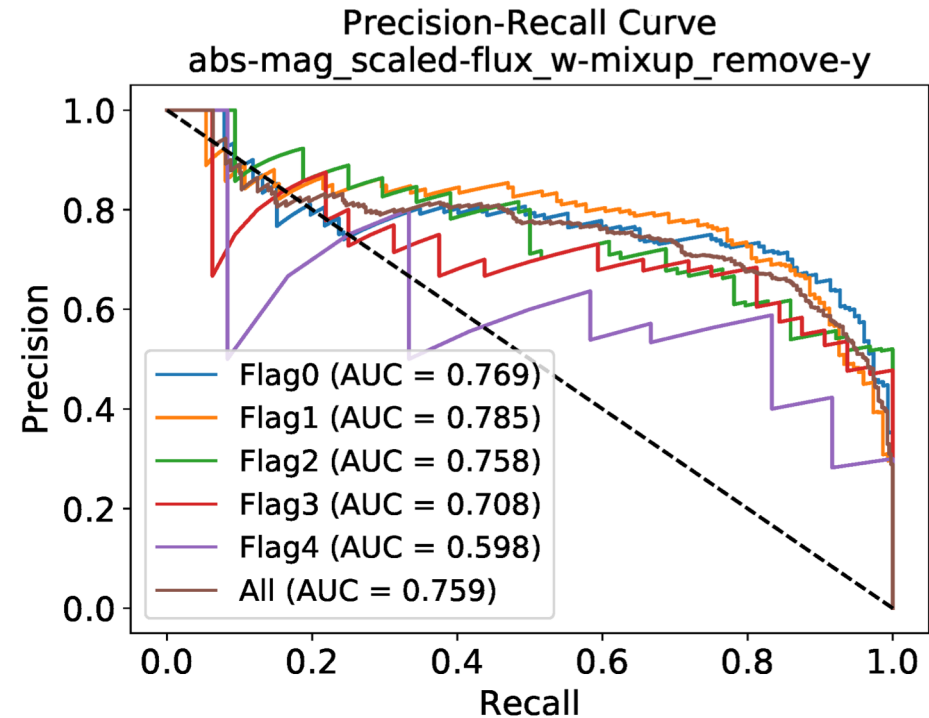
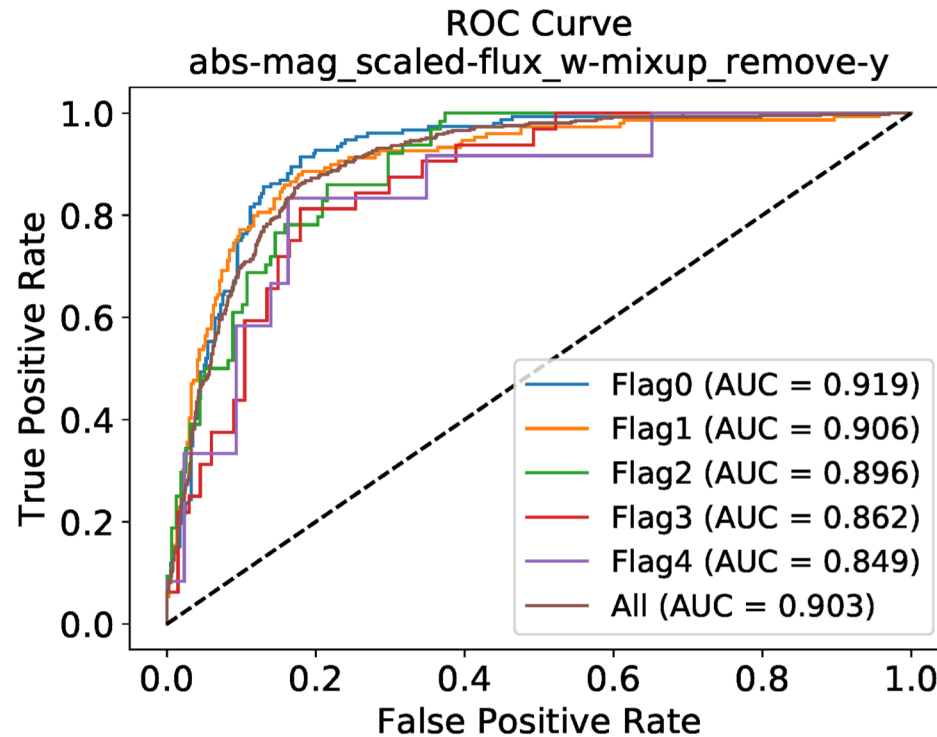
Kappa coefficient : 0.916

Apply to HSC data

2class, True label : SALT2 LC fit

All labeled SNe (1540/1824)

Takahashi + in prep.

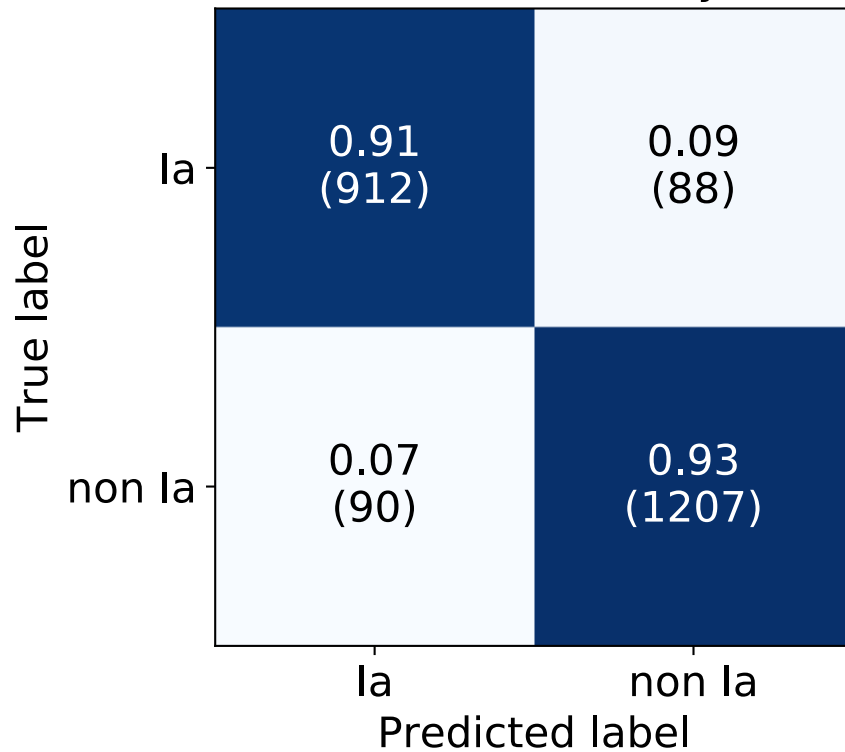


| Flag | input | SN number | Cumulate_ratio |
|------|-------|-----------|----------------|
| 0 | 52 | 705 | 0.387 |
| 1 | 32 | 651 | 0.743 |
| 2 | 23 | 271 | 0.892 |
| 3 | 12 | 121 | 0.958 |
| 4 | 6 | 64 | 0.993 |

Comparison with PLAsTiCC 1st prize classifier

PLAsTiCC 1st prize classifier

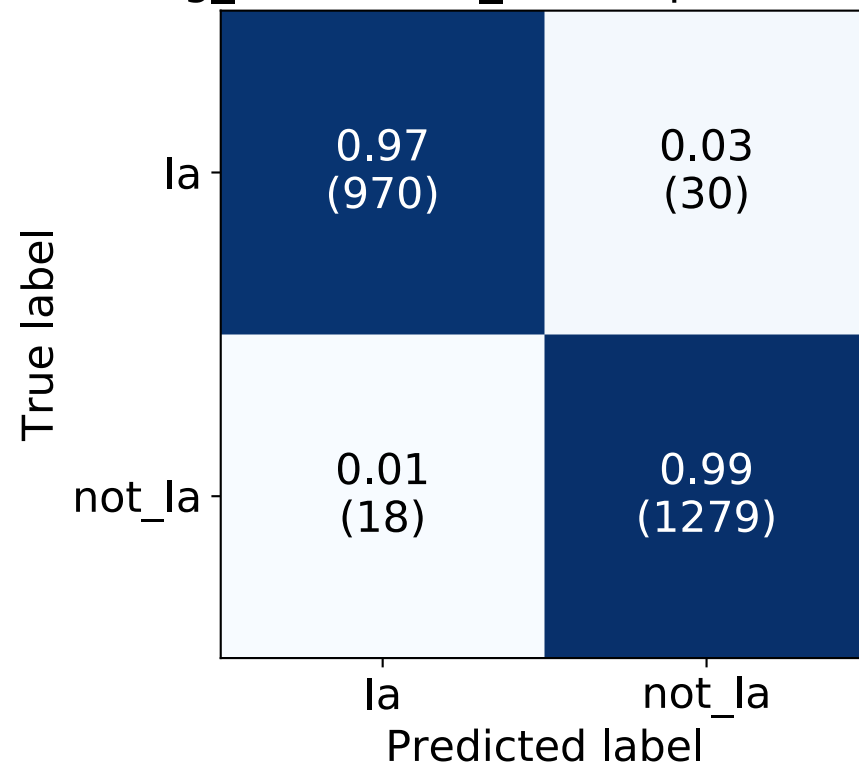
Normalized confusion matrixn,
PLAsTiCC-1st, accuracy:0.923



Kappa coefficient : 0.842

Our classifier

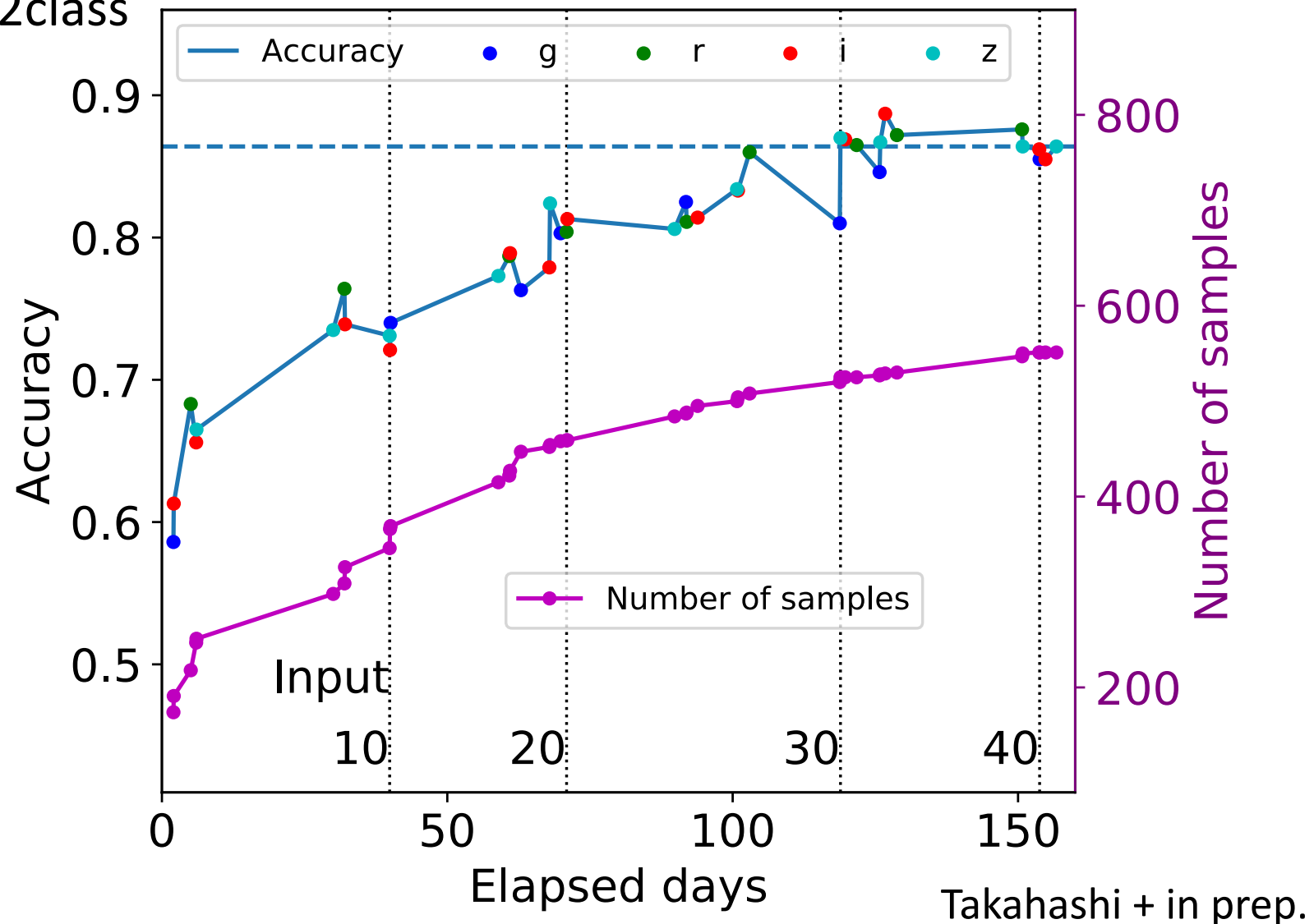
Normalized confusion matrixn,
abs-mag_scaled-flux_w-mixup, accuracy:0.979



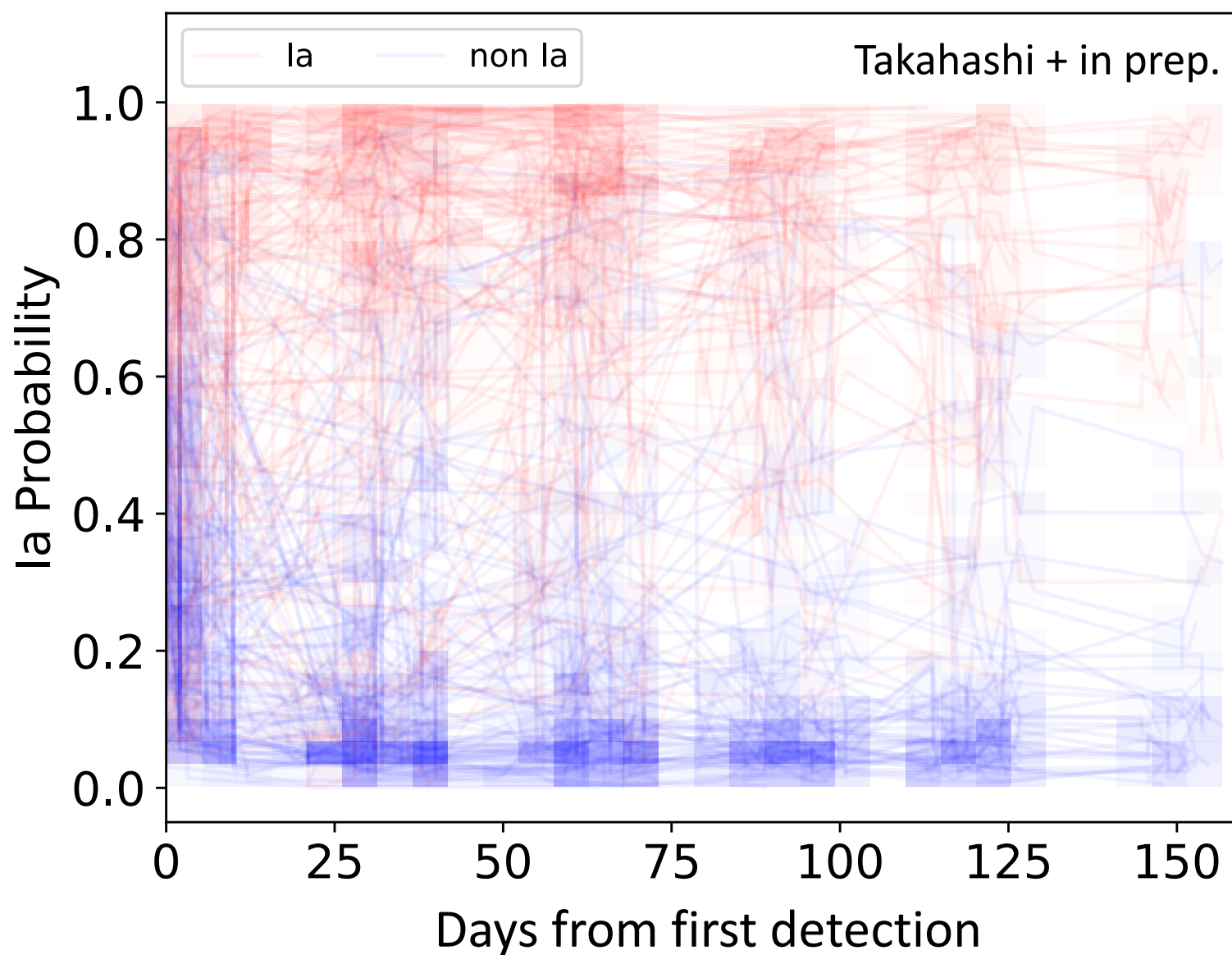
Kappa coefficient : 0.957

Classification performance against number of inputs

HSC 2class



Ia probability transition along the supernova phase



Summary

- We tried the classification by machine learning to classify supernovae which have increased rapidly in recent years.
- The classification results of the prototype classifier became one of the criteria for selecting follow-up targets in the HSC transient survey 2016.
- After the HSC survey, we improved the classifier by adopting PLAsTiCC templates and optimizing the classifier model.
- The improved classifier classifies type Ia supernovae with 97% accuracy for the PLAsTiCC DDF dataset, and has a classification performance of about 0.9 in AUC for actual HSC survey data.
- We are now in the middle of another HSC transient survey and are classifying the actual supernovae again with this improved classifier.